Exhibit 13

United States Patent [19]

Hamada

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[45] **Date of Patent: Oct. 1, 1991**

[54] **PROJECTION TYPE IMAGE DISPLAY APPARATUS**

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[21] Appl. No.: **423,335**

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[30] **Foreign Application Priority Data**

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[51] **Int. Cl.**[5] **G02F 1/13**

[52] **U.S. Cl.** **359/40**; 359/54; 359/49

[58] **Field of Search** .... 350/331 R, 334, 339 R, 350/345, 114, 347 V

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60-165623	8/1985	Japan .	
60-165624	8/1985	Japan .	
60-262131	12/1985	Japan .	

Primary Examiner—Rolf Hille
Assistant Examiner—Tan Ho

[57] **ABSTRACT**

In a liquid crystal image display apparatus, an image of pixels of a liquid crystal display panel are projected onto a projection surface. The apparatus includes a light source, the liquid crystal display panel, microlens arrays provided respectively at a side of the liquid crystal display panel facing the light source and at another side thereof facing the projection surface, and a condenser lens provided between the light source and the microlens array located at the light source side of the display panel. The microlens arrays include a plurality of microlenses provided in positions corresponding to the plurality of pixels of the liquid crystal display panel, and pitches of the microlenses of the microlens array at the light source side are set to be larger than pitches of the pixels, while the pitches of the microlenses of the microlens array at the projection surface side are set to be smaller than those of the pixels.

18 Claims, 7 Drawing Sheets

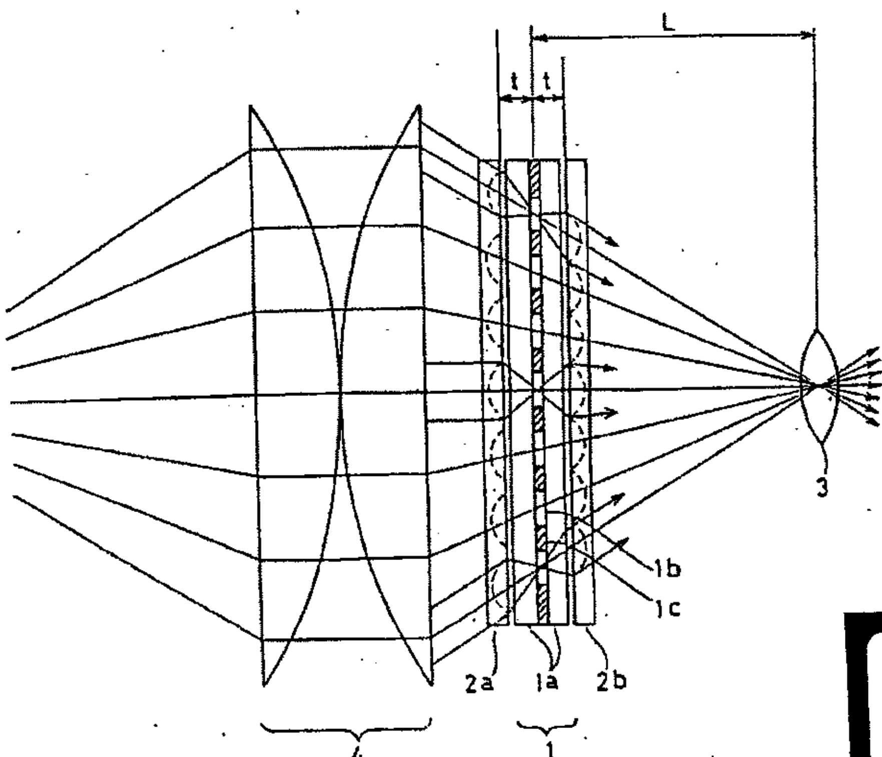


FIG.1 PRIOR ART

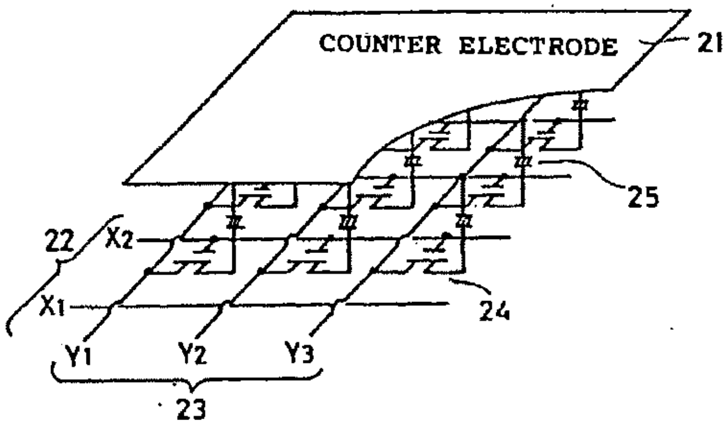


FIG.2 PRIOR ART

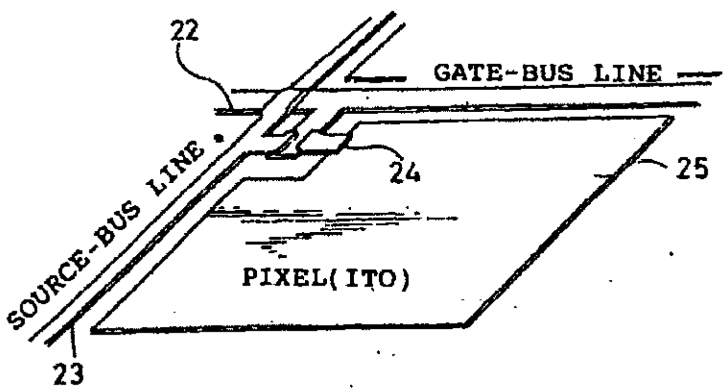
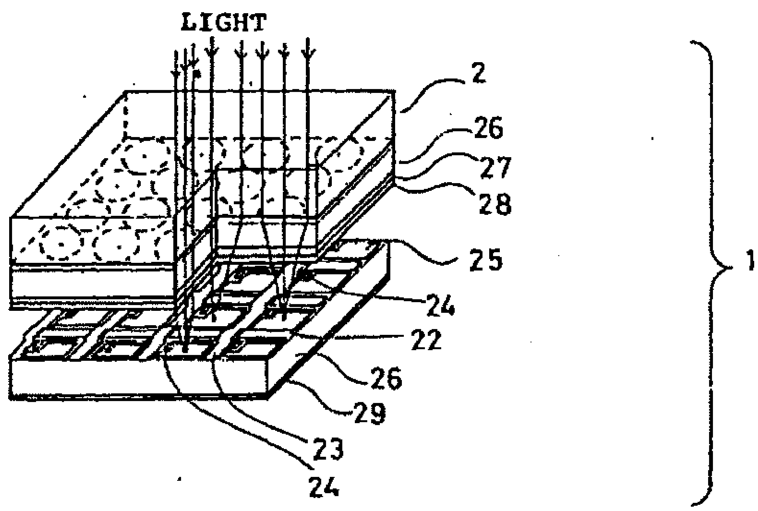


FIG.3

PRIOR ART



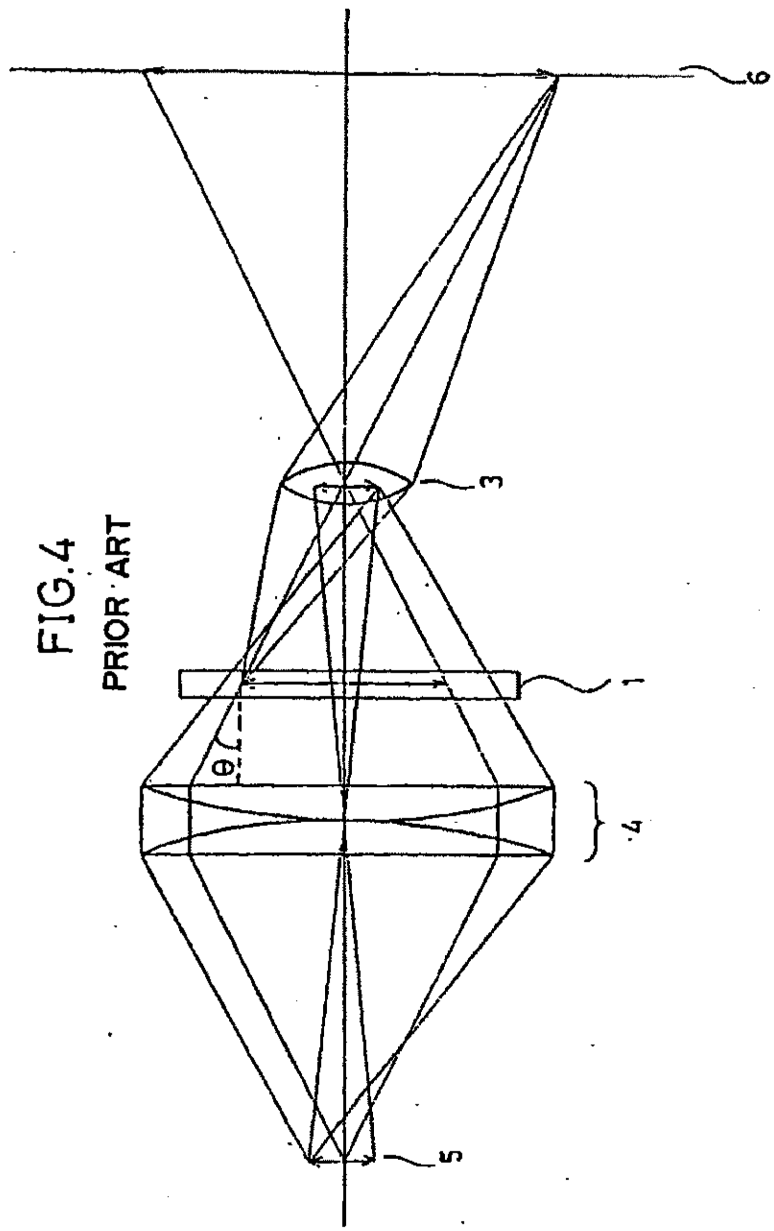


FIG.4
PRIOR ART

FIG.5A PRIOR ART

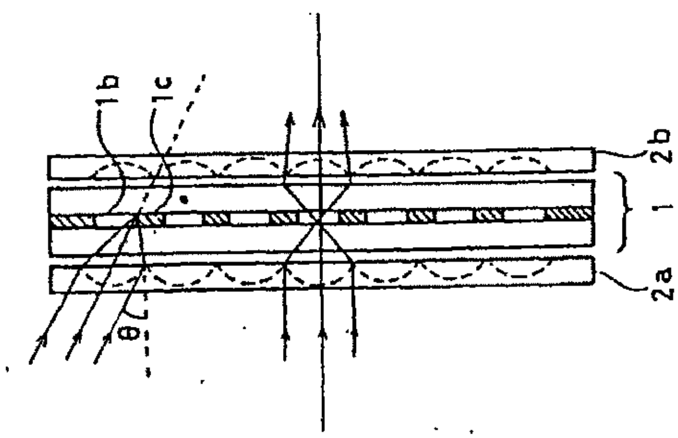
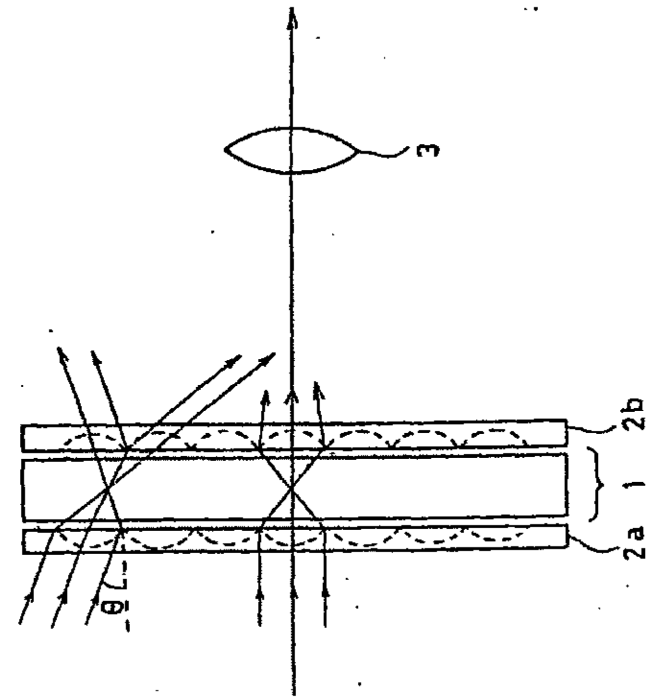


FIG.5B PRIOR ART



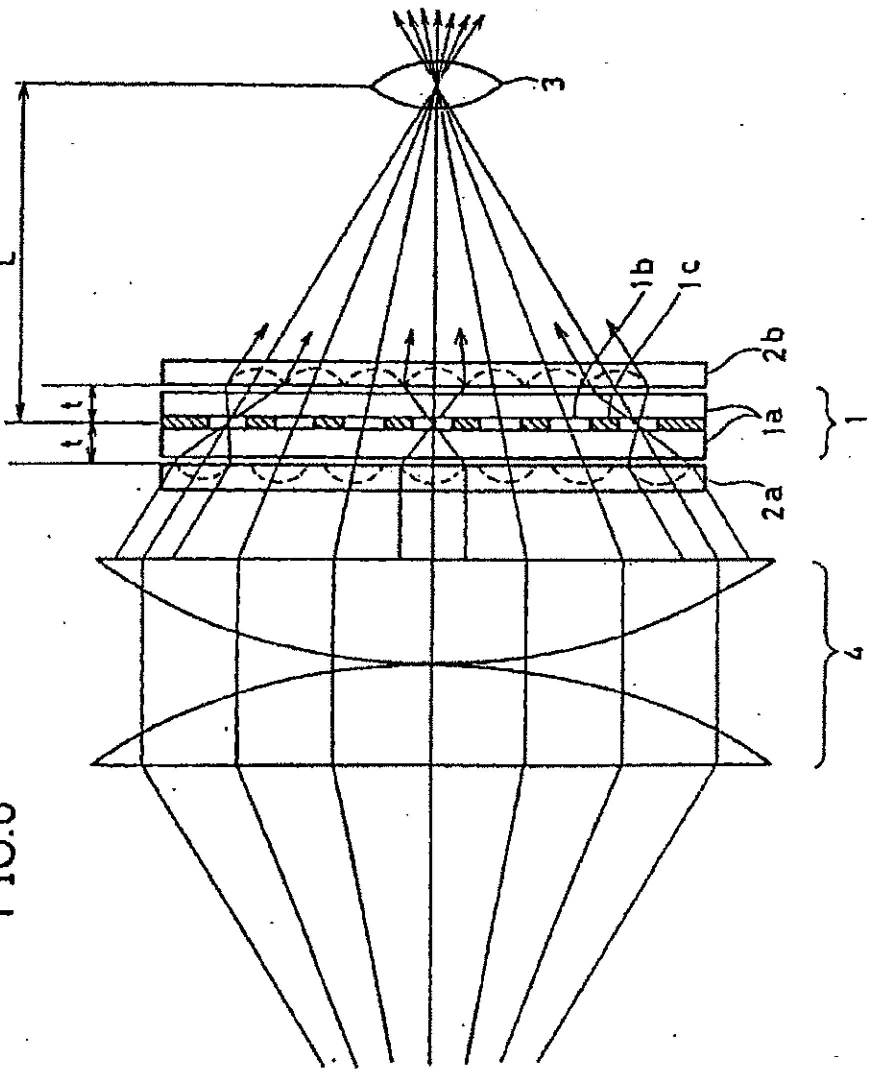


FIG.6

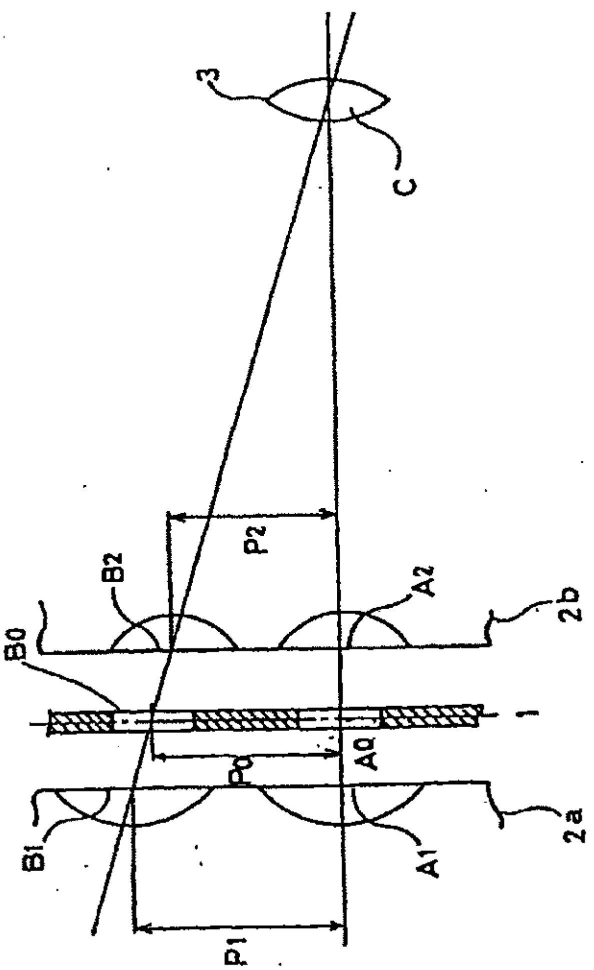
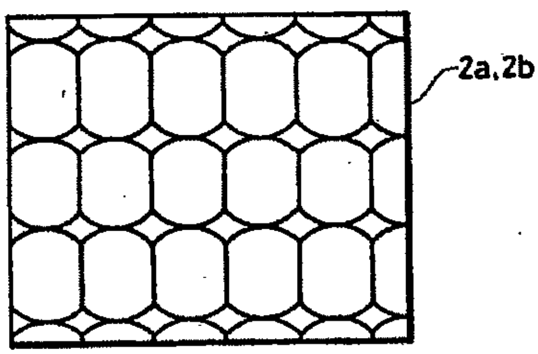


FIG.7

FIG.8



PROJECTION TYPE IMAGE DISPLAY APPARATUS

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates generally to a projection type image display apparatus comprising non-emissive display panels of a matrix type (e.g., liquid crystal display panels) and microlens arrays. More particularly, it relates to the projection type image display, apparatus in which a bright display is achieved over the entire region of the panel.

DESCRIPTION OF THE BACKGROUND ART

A non-emissive display panel employed in the present invention, which does not emit light per se, has its light transmittance varied by a driving signal. Images and characters are displayed by modulating the intensity of light emitted from an external light source. Examples of the non-emissive display panel, are a liquid crystal display panel, an electrochromic display, and a display using PLZT as an electro optical material or the like. The liquid crystal display panel is particularly widely used for portable TV, word processors and the like. Minimum display units called pixels are regularly provided in such a panel. Application of individual drive voltages to the respective pixels causes the images and characters to be displayed. As a method of applying the individual drive voltages to the respective pixels, there exists a simple matrix driving method and an active matrix driving method. FIG. 1 shows a schematic equivalent circuit of a liquid crystal display panel employing active matrix driving. Referring to FIG. 1, the active matrix driving type liquid crystal display panel comprises TFTs 24 provided in matrix at respective intersections of X electrodes 22 and Y electrodes 23, with liquid crystal elements 25 forming pixels connected to the TFTs 24. FIG. 2 is a diagram illustrating in detail the periphery of one of the pixels shown in the FIG. 1. Referring to FIG. 2; a thin film transistor TFT 24 is provided at an intersection of a gate bus line corresponding to one of the X electrodes 22 and a source bus line corresponding to one of the Y electrodes 23, with a drain thereof connected to the pixel electrode 25.

In the active matrix type liquid crystal display apparatus, driving signal lines, gate bus lines and source bus lines, for supplying the drive voltages to the respective pixels need be provided among the pixels. Therefore, the ratio of a pixel region occupying a screen (aperture) decreases. A portion of the light illuminating the panel, which impinges on portions other than the pixel region, does not contribute to the display and thus becomes useless. Therefore, there was a disadvantage that the screen became darker as the aperture of the panel decreased even if the same light source was employed.

To eliminate this disadvantage, a microlens array (in which microlenses are regularly arranged in two dimensions) is employed to the display panel. Convergence of the illuminating light on the pixel region results in enhanced brightness of the display screen. The details of this process is disclosed in, for example, Japanese Laid Open Patent Nos. 60-165621-165624 and 60-262131.

FIG. 3 is a perspective view illustrating a state that the microlens array 2 is attached to the active matrix type liquid crystal display apparatus 1. Referring to FIG. 3, the active matrix type liquid crystal display apparatus 1 comprises a pixel electrode 25, shown in

FIG. 1, an aligning layer/counter electrodes 28 provided on the pixel electrode 25 (now shown) and on the place opposing the pixel electrode 25, a glass substrate 26 provided below the pixel electrode 25, a color filter 27 provided above the aligning layer/counter electrode 28, and another glass substrate 26 provided above the color filter 27.

As shown in FIG. 3, each of the microlenses is provided in a position corresponding to one pixel of the display panel. The light from the light source impinges on each pixel electrode 25 through each microlens. Thus, pitches of the microlenses constituting the microlens array 2 have been made equal to pitches of the pixels of the display panel 1.

FIG. 4 is a diagram illustrating a principle of image projection in a conventional projection type image display apparatus. A projection optical system being the same as that used in a slide projector, is employed. The non-emissive display panel 1 is provided in place of a slide, and an image displayed on the display panel is projected in magnification by employing the light source. An image of the light source 5 is formed in a projection lens 3 in this optical system, as shown in FIG. 4. The image on the display panel 1 is projected on a screen 6 through the projection lens 3. In this case, light from the light source 5 is converged by a condenser lens 4 at the periphery of the display panel 1 (i.e., a position apart from an optical axis in this figure,) but passes obliquely rather than normally to the display panel 1. This angle θ deviated from the right angle becomes larger This as the display panel 1 becomes larger or a distance between the display panel 1 and the projection lens 3 becomes shorter.

FIGS. 5A and 5B are enlarged views of the periphery of the display panel 1 shown in FIG. 4. Referring to the FIGS. 5A and 5B, the display panel 1 comprises pixel regions 1*b* and bus lines or TFT regions 1*c*. Microlenses, arrays 2*a* and 2*b* including a plurality of microlenses arranged in the same pitches as those of the pixels of the display panel, are provided respectively at opposite sides of the display panel 1, i.e., at the side facing the light source with the other side facing the projection lens.

Referring to these figures, in the case that the pitches of the pixels of the display panel are equal to those of the microlenses of the microlens arrays, an increase of the deviation angle θ causes the following two phenomena.

(1) The light from the light source is focused near the pixels by the microlenses at the side facing the light source to form an image of the light source. However, if the angle θ is large, the image of the light source extends beyond the pixel regions 1*b*, as shown in FIG. 5A. The light impinges absorbed or scattered on non-display region and thus becomes useless.

(2) As shown in FIG. 5B, the light passing through the center of the microlenses 2*a* at the side facing the light source does not pass through the center of the microlenses 2*b* at the side facing the projection lens. Therefore, the incident light changes its direction so as to not be directed toward the projection lens 3. The angle θ between the optical axis and the angle of the incidence of the light becomes larger as it becomes distant from the center of the screen. Thus, a projected image becomes darker as it becomes distant from the center of the screen due to these phenomena.

SUMMARY OF THE INVENTION

It is an object of the present invention to prevent darkening of even the periphery of a projected image in a projection type image display apparatus.

It is another object of the present invention not to prevent making pitches of microlenses of a microlens array equal to pitches of pixels of a liquid crystal display apparatus in the projection type image display apparatus.

It is a further object of the present invention to have light, which passes through the center of microlenses at the side facing a light source, pass through the pixels and through the center of microlenses at the side facing a projection lens, in the projection type image display apparatus.

The above described objects of the present invention are achieved by the f[illegible] the pro[illegible]ction type image display apparatus c[illegible] the [illegible]ng. [illegible]at is, the projection type image display apparatus, for projecting light from the light source onto a non-emissive display portion according to the present invention and then projecting an image of the display portion on a predetermined projection screen, comprises a display panel in which a plurality of pixels arranged apart from each other by a predetermined first spacing in a matrix, a first microlens array provided at the side of the display panel facing the light source, which includes a plurality of microlenses arranged apart from each other by a predetermined second spacing in corresponding positions of the plurality of pixels on the display panel, and a second microlens array provided at the other side of the display panel facing the projection screen, which includes a plurality of microlenses arranged in corresponding positions of the plurality of pixels on the display panel. Furthermore, the first and second spacings are selected to be different from each other.

Since the projection type image display apparatus according to the present invention comprises the above described elements, pitches of the microlenses facing the light source differs from pitches of the pixels on the display panel. Therefore, the pitches of the microlenses are determined such that the light from the light source passing through the periphery passes through the center of the corresponding pixels on the display panel. As a result, even the periphery of a projected image does not become darker in the projection type image display apparatus.

Preferably, a condenser lens is provided between the light source and the display portion to focus the light from the light source on the side facing the projection screen, and the second spacing is selected to be larger than the first spacing; and further, the plurality of microlenses of the second microlens array are arranged apart from each other by a predetermined third spacing, which is selected to be smaller than the first spacing.

More preferably, since the projection type image display apparatus according to the present invention comprises the above described elements, the light passing through the center of the microlenses at the side facing the light source passes through the center of the microlenses at the side facing the projection lens. Therefore, the incident light is effectively directed to the projection lens without changing its direction. Consequently, the projected image over the entire screen has a predetermined brightness in the projection type image displa[illegible] paratus.

The foregoing and other objects, features, aspects and advantages of the present invention will become more apparent from the following detailed description of the present invention when taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic equivalent circuit diagram of a liquid crystal display panel of active matrix type;

FIG. 2 is an enlarged view of the periphery of one of the pixels of the liquid crystal display panel shown in FIG. 1;

FIG. 3 is a perspective view illustrating a state that a microlens array is attached onto an active matrix type liquid crystal display apparatus;

FIG. 4 is a diagram illustrating an image projection optical system of the projection type image display apparatus;

FIGS. 5A and 5B are enlarged views of the display panel portion shown in FIG. 4;

FIG. 6 is a top view of the projection type image display apparatus to which the present invention is applied;

FIG. 7 is a view illustrating a relationship between pitches of pixels of the display panel and those of microlenses of the microlens array; and

FIG. 8 is a plan view of a microlens array in which boundaries of each microlens are partially fused.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIG. 6, a liquid crystal display panel 1 of the matrix type and an equivalent type and equivalent type has pixels which are display units arranged regularly in a portion sandwiched between substrates *1a*. A microlens array *2a* having larger pitches than those of the pixels is attached to the front of the liquid crystal display panel 1. A condenser lens 4 and a light source 5 (not shown) are provided in front of the microlens array *2a*. A microlens array *2b* having smaller pitches than those of the pixels is attached to the rear of the liquid crystal display panel 1. A projection lens 3 and a screen 6 (not shown) are provided further in the rear of the panel. It is now assumed that a distance from the center of the liquid crystal display panel 1 to the projection lens 3 is represented by L. A distance between a surface in which the pixels of the display panel 1 are arranged and a plane surface in which the microlens array *2a* and *2b* is provided is represented by t, which is nearly equal to a thickness of the substrate *1a* of the display panel 1.

As shown in FIG. 6, the microlens arrays *2a* and *2b* display panel 1. This arrangement, however, is made only for convenience of a description thereof, and thus, in practicality, there is no spacing between these microlens arrays.

Light from the light source, not shown, is converged by the condenser lens 4 and transmitted through the microlens array *2a*, the liquid crystal display panel 1 and the micrlens array *2b* to be imaged on the projection lens 3 and projected on the screen, not shown.

A description will be given of the relationship between a lens pitch of the micrlens arrays and a pixel pitch of the liquid crystal display panel 1 with reference to FIG. 7. For simplification, the relationship will be described between a pixel at the center of the screen (on an optical axis) and an adjacent pixel. A central portion of the pixel at the center of the screen is represented by An. the central portions of the corresponding micro-

lenses are respectively represented by A_1 and A_2, the adjacent pixel is B_0, and the central portions of their corresponding microlenses are B_1 and B_2. Since a liquid crystla layer is several μm thich, it is negligible in this figure.

A length between $\overline{A_0B_0}$ is represented by P_0 (the pixel pitch), and $\overline{A_1B_1}=P_1$, $\overline{A_2B_2}=P_2$ (the pitches of the microlenses).

$\overline{A_0A_1}$ and $\overline{A_0A_2}$ both are equal to the value t/n, which is obtained by dividing the thickness t of the substrate of the liquid crystal panel by a refractive index n of the substrate in order to convert the t into an optical path length in the air.

Assuming that the location of the projection lens 3 on the optical axis is C, triangles A_0B_0C, A_1B_1C and A_2B_2C are similar to one another.

Therefore, the following equalities are given:

$$\begin{aligned} P_1/P_0 &= \overline{A_1C}/\overline{A_0C} \\ &= (L + t/n)/L \\ &= 1 + t/(n \cdot L) \end{aligned} \tag{1}$$

$$\begin{aligned} P_2/P_0 &= \overline{A_2C}/\overline{A_0C} \\ &= (L - t/n)/L \\ &= 1 - t/(n \cdot L) \end{aligned} \tag{2}$$

That is, if the pixel pitch and the pitches of the microlenses are selected in such relationship as expressed in the above equalities (1) and (2), the light from the light source passes through the central portions of the microlenses and the pixels. As a result, a projected image does not become darker at the central portion of the display panel nor at the peripheral portion thereof in the projection type image display apparatus such as the active matrix type liquid crystal display apparatus.

A practical application of the present invention will now be described. Such a case will be described that the present invention is applied to a liquid crystal display panel employed for a pocket type liquid crystal color TV ,,. (the apparatus type number 3C-EI, 3E-J1, for example), which is put in the market by the applicant of the present invention as the liquid crystal display panel. The size of a screen of this liquid crystal display panel is 45.6 mm high by 61.8 mm wide. The pixel pitch P_0 is 190. μm in the vertical direction and 161 μm in the horizontal direction, the thickness t of the substrate is 1.1 mm, and the refractive index n of the substrate is 1.5. A focal length of the projection lens is 200 mm, and L is approximately 200 mm.

The microlens array is manufactured by a method of obtaining a refractive index profile type lens by selective ion diffusion (Electronics Letters Vol. 17 No. 13 p. 452 (1981)). In this method, a glass plate is dipped in molten salt. A kind of metal ion, such as alkaline ions, are exchanged between the glass plate and the molten salt through a mask provided on the glass plate. As a result, the glass plate is obtained which has refractive index profile corresponding to a mask pattern.

The pitch of the microlens array *2a* at the side facing the light source is determined to be 190.7 μm in the vertical direction and 161.6 μm in the horizontal direction according to the equation (1). The pitch of the microlens array *2b* at the side facing to the projection lens is determined to be 189.3 μm in the vertical direction and 160.4 μm in the horizontal direction according to the equation (2). Correction of the pitches is not carried out for comparison, and a microlens array having the same pitch as the pixel pitch is also manufactured. Each microlens has a diameter of 150 μm and a focal length of 720 μm (=t/n) in the atmosphere.

Such a microlens array is employed for a projection type color liquid crystal display apparatus.

Only the central portion of the screen is effectively used for projection in the one in which the pitch correction of the microlens array is not carried out. The reason for this will be described as follows. That is, the light from the condenser lens 4 does not enter at the right angle to the liquid crystal display panel 1 but at a certain angle θ in the end portions of the display panel 1.

In this case, the angle θ is expressed as follows.

$$\begin{aligned} \tan\theta &= \{(\text{the width of the display panel})/2\}/L \\ &= \{(61.8)/2\}/200 \\ &= 0.1545 \end{aligned}$$

In the case of no pitch correction of the microlens array, the light, which passes through the center of the microlenses at the side facing the light source and is then directed to the center of the projection lens, passes (t/n) x tan θ=113 μm apart from the center of the pixels. This deviation is larger than half the pixel pitch, so that it extends to the adjacent pixel. Furthermore, this light passes 226 μm apart from the center of the microlenses at the side facing the projection lens. This deviation is larger than one pixel pitch of the microlens array, and thus does not reach the projection lens.

Meanwhile, in the case of correcting the pitch of the microlens array according to the present invention, the light from the light source can effectively be utilized in even the peripheral portion of the projected image. Therefore, distribution of luminance becomes uniform over the entire screen, resulting in enhanced visibility.

In the above described embodiment, since the condenser lens 4 is provided at the side of the liquid crystal display panel facing the light source, the pitch of the microlens array at the light source side is made larger than the pixel pitch. On the other hand, if the condenser lens 4 is provided at the projection lens side, the pixel pitch is made larger than the pitch of the microlens array. No change can be seen in the capacity of light convergence in either case of facing a convex surface of the microlens array toward the display panel or away from it. However, the distance t varies, which is between the plane surface on which the pixels of the display panel are arranged and the surface on which the microlens array is provided. Therefore, the pitch and focal length of the microlens array need be varied in accordance with the variation of the distance t.

The present invention can also achieve the same effect when applied to a cylindrical lens (a semicylindrical lens or a lenticular lens) as it is applied to the spherical lens array as described above.

When the pitch of the pixels of the display panel in the width direction differs from that if the height direction, a microlens array in which boundaries of each microlens are partially fused may be used. In this case, an area to receive light can be increased. An example of such a lens is shown in FIG. 8.

The description of the present invention has been given with respect to the case of employing the microlens array formed by the method of obtaining the refractive index profile type lens through the selective ion

diffusion. As a matter of course, the present invention is also applicable to a microlens array formed by another method.

Although the present invention has been described and illustrated in detail, it is clearly understood that the same is by way of illustration and example only and is not to be taken by way of limitation, the spirit and scope of the present invention being limited only by the terms of the appended claims.

What is claimed is:

1. A projection type image display apparatus in which light from a light source is projected through a projection lens onto a non-emissive display portion, and an image of the display portion is then projected onto a predetermined projection surface,

the display portion comprising:

a display panel, including a substrate of a refractive index n, on which a plurality of pixels are arranged in a matrix, separated from each other by a predetermined first pitch P_0; and

first microlens array, provided between the display panel and the light source, the first microlens array including a plurality of microlenses separated from each other by a predetermined second pitch P_1 and arranged in positions corresponding to the plurality of pixels on the display panel,

said first pitch P_0 and said second pitch P_1 being of different values and

satisfying the equation,

$P_1 = P_0 \cdot \{1 + t/(n+L)\}$, wherein t equals the distance between the display panel and the first microlens array and L equals the distance between the projection lens and the display panel.

2. A projection type image display apparatus according to claim 1, further comprising:

a second microlens array, provided between the display panel and the projection surface, the second microlens array including a plurality of microlenses arranged in positions corresponding to the plurality of pixels on the display panel.

3. A projection type image display apparatus according to claim 2, wherein

said plurality of microlenses of said second microlens array are separated from each other by a predetermined third pitch P_2, and wherein

said third pitch P_2 is smaller in value than said first pitch P_0.

4. A projection type image display apparatus according to claim 3, wherein

said plurality of pixels are arranged on a first plane surface on said display panel;

said plurality of microlenses on said first microlens array are provided on a second plane surface;

said plurality of microlenses of said second microlens array are provided on a third plane surface;

wherein a distance between said first plane surface and either of said second and third plane surfaces is t, and

pitch P_2 of said array satisfies the following expression,

$$P_2 = P_0 \ \{1 - t/(n \cdot L)\}.$$

5. A projection type image display apparatus according to claim 4, wherein

said plurality of pixels are formed in rows of a first direction and in rows of a second direction perpendicular to said first direction;

said plurality of microlenses of said first and second microlens arrays are provided in said first direction and in said second direction;

said plurality of microlenses formed in said second direction are integrated; and

said first and second microlens arrays include cylindrical lenses separated from each other by the predetermined second pitch P_1 in said first direction.

6. A projection type image display apparatus according to claim 5, wherein

said cylindrical lenses include semicylindrical lenses.

7. A projection type image display apparatus according to any one of claims 1 and 2, further comprising:

at least one condenser lens the light source and the display panel, for focusing light from the light source onto the predetermined projection surface, wherein the

first pitch P_1 is smaller in value than the second pitch P_1.

8. An image display device comprising:

display panel on which a plurality of pixels are arranged in a matrix, separated from each other by a predetermined first pitch;

first microlens array, provided between said display panel and a light source, including a plurality of microlenses separated from each other by a predetermined second pitch and arranged in positions corresponding to the plurality of pixels on the display panel; and

second microlens array, provided between said display panel and an image display surface, including a plurality of microlenses separated from each other by a predetermined third pitch and arranged in positions corresponding to the plurality of pixels on the display panel,

said predetermined first, second, and third pitch each being of a different value.

9. The image display device of claim 8 wherein,

said first pitch is larger in value than said third pitch.

10. The image display device of claim 8 wherein,

said second pitch is larger in value than said first pitch.

11. The image display device of claim 10 wherein,

said first pitch is larger in value than said third pitch.

12. A projection type image display apparatus in which light from a light source is projected through a projection lens onto a non-emissive display portion, and an image of the display portion is then projected onto a predetermined projection surface,

said display portion comprising:

a display panel on which a plurality of pixels are arranged in a matrix, separated from each other by a predetermined first pitch; and

first microlens array, provided between the display panel and the light source, and including a plurality of microlenses separated from each other by a predetermined second pitch and arranged in positions corresponding to the plurality of pixels on the display panel,

said predetermined first pitch being smaller in value than said predetermined second pitch.

13. A projection type image display apparatus according to claim 12, further comprising:

second microlens array, provided between the display panel and the predetermined projection surface, and including a plurality of microlenses arranged in positions corresponding to the plurality of pixels on the display panel

14. A projection type image display apparatus according to claim 13, wherein

said plurality of microlenses of said second microlens array are separated from each other by a predetermined third pitch, and

said third pitch is smaller in value than said first pitch.

15. A projection type image display apparatus according to claim 14, wherien

said plurality of pixels are arranged on a first plane surface on said display panel;

said plurality of microlenses on said first microlens array are provided on a second plane surface;

said plurality of microlenses of said second microlens array are provided on a third plane surface;

wherein a distance between said first plane surface and either of said second and third plane surfaces is t,

a refractive index of a substrate of the display panel is n,

a distance between the display panel and the projection lens is L,

said first pitch is P_0, said second pitch is P_1, and said third pitch is P_2, and

pitches P_1 and P_2 of said first and second microlens arrays are selected to satisfy the following expressions:

$$P_1 = P_0 \cdot \{1 + t/(n \cdot L)\}$$

$$P_2 = P_0 \cdot \{1 - t/(n \cdot L)\}$$

16. A projection type image display apparatus according to claim 15, wherein

said plurality of pixels are formed in rows of a first direction and in rows of a second direction perpendicular to said first direction;

said plurality of microlenses of said first and second microlens arrays are provided in said first direction and in said second direction;

said plurality of microlenses formed in said second direction are integrated; and

said first and second microlens arrays include cylindrical lenses separated from each other by the predetermined second pitch in said first direction.

17. A projection type image display apparatus according to claim 16, wherien

said cylindrical lenses include semicylindrical lenses.

18. A projection type image display apparatus according to any one of claims 12 and 13, further comprising:

condenser lens, provided between the light source and the display panel, for focusing light from the projection surface.

* * * * *

Exhibit 14

US005128783A

United States Patent [19]

Abileah et al.

[11] **Patent Number: 5,128,783**

[45] **Date of Patent: Jul. 7, 1992**

[54] **DIFFUSING/COLLIMATING LENS ARRAY FOR A LIQUID CRYSTAL DISPLAY**

[75] Inventors: **Adiel Abileah**, Farmington Hills; **Charles Sherman**, Royal Oak, both of Mich.

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[21] Appl. No.: **473,039**

[22] Filed: **Jan. 31, 1990**

[51] Int. Cl.^{5} **G02F 1/13**

[52] U.S. Cl. **359/49**; 359/48; 359/54; 359/40; 362/268; 362/297

[58] Field of Search .... 350/338, 339 D, 334, 350/345, 333, 237, 321, 483; 362/268, 297, 342, 335, 347, 355

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[57] **ABSTRACT**

Improved backlighting for a liquid crystal display is provided by an integral diffusing/collimating lens fabricated from a translucent optical media in which glass beads are suspended. The optical media is configured in substantially the same shape as the array of lamps which illuminate the backlit display and serves as both a lens and a diffuser. The lens effect is obtained by positioning the optical media so that the focal length thereof is at the lamp location. In this manner, the optical media behaves as a collimating lens. The optical effect simultaneously occurs at the air-to-material interface. Of course, the translucent material from which the media is fabricated diffuses light so as to uniformly distribute light emanating from said lamps in all directions.

19 Claims, 2 Drawing Sheets

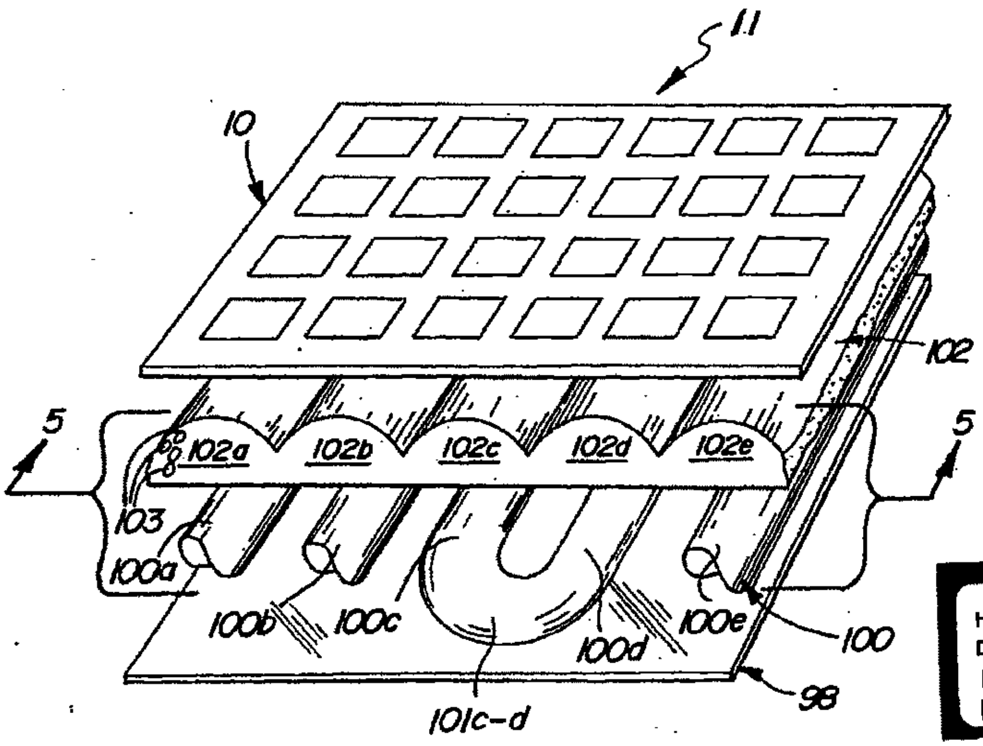

FIG. 1

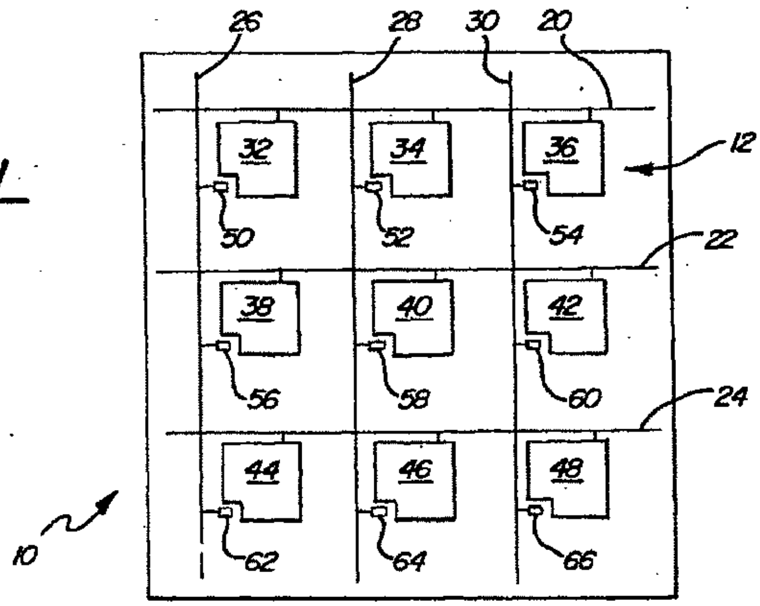

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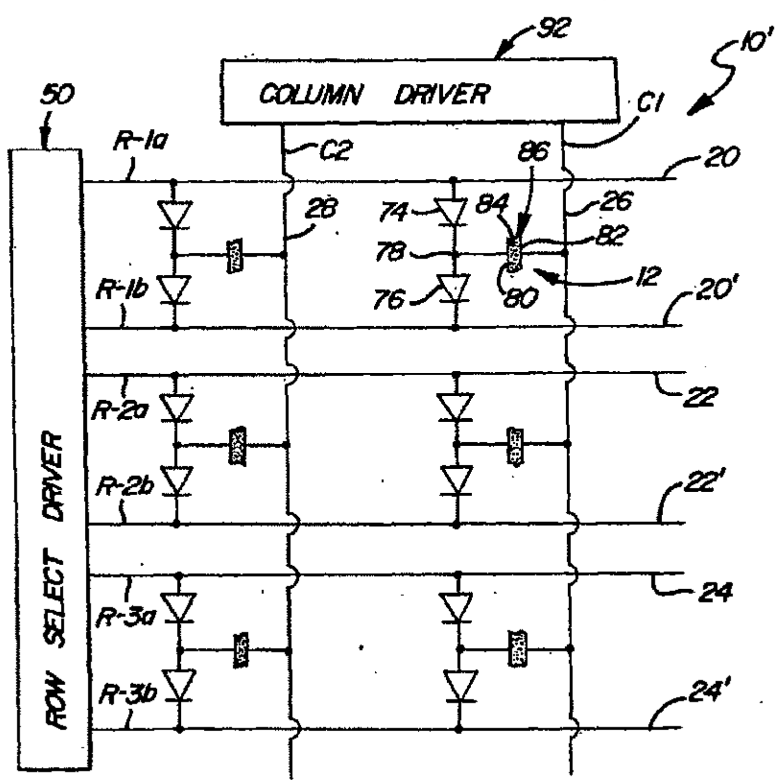
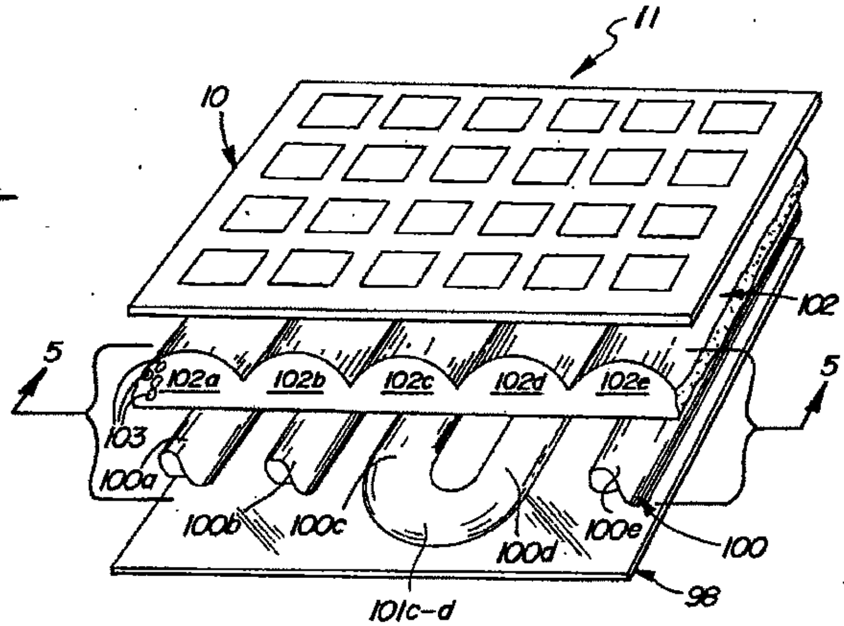
FIG. 2



92
10'
COLUMN DRIVER
50
C1
R-1a
C2
86
20
28
74
84
26
78
82
R-1b
12
76
80
20'
22
R-2a
R-2b
22'
24
R-3a
R-3b
24'
ROW SELECT DRIVER

FIG. 3



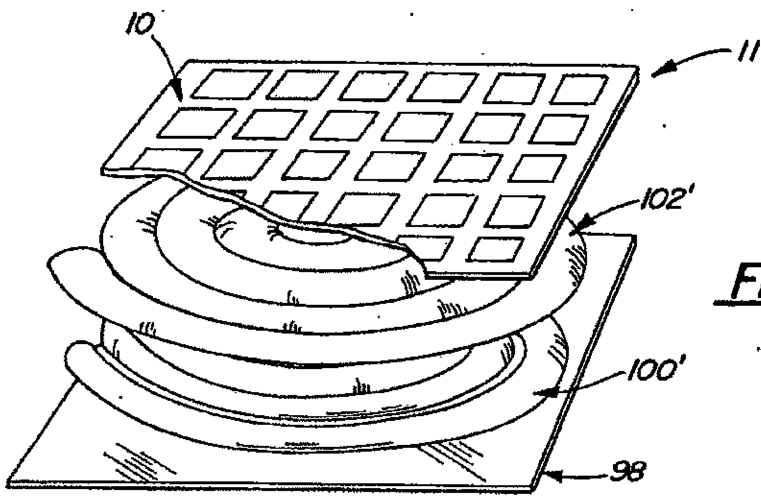
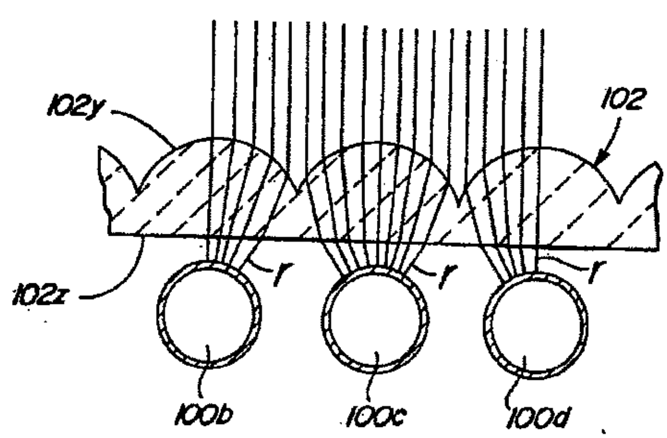


FIG. 4

FIG. 5



DIFFUSING/COLLIMATING LENS ARRAY FOR A LIQUID CRYSTAL DISPLAY

FIELD OF THE INVENTION

The instant invention relates generally to the field of electronic two dimensional liquid crystal displays, which displays are adapted to provide either still or video images to a remotely positioned viewing audience. The instant invention more particularly relates to the field of backlit active matrix liquid crystal displays having both a light diffusing element and a light collimating element included therein for enhancing the quality of the displayed image while simultaneously decreasing the profile i.e., the depth dimension of those displays.

BACKGROUND OF THE INVENTION

In recent years, a considerable amount of research has been conducted in an effort to develop a low profile (thin), full color, electronic display system which does not rely upon conventional cathode ray tube technology. In systems such as television receivers, computer monitors, avionic displays, aerospace displays, and other military-related displays, the elimination of cathode ray tube technology is desirable for several reasons, which reasons will be detailed in the following paragraphs.

More particularly, cathode ray tubes are typically characterized by extremely large depth dimensions and thus occupy a considerable amount of floor or counter space. As a matter of fact, the depth dimension may equal the length and width dimensions of the viewing screen. Also, because cathode ray tubes require an elongated neck portion to provide for the acceleration of an electron beam from the electron gun to the faceplate of the cathode ray tube, they are quite irregular in shape. Additionally, since cathode ray tubes are fabricated from relatively thick glass, they are inordinately heavy, extremely fragile and readily breakable. Finally, cathode ray tubes require a relatively high voltage power supply in order to sufficiently accelerate the electron beam and thus sustain the displayed image.

The reader can readily appreciate the fact that all of the foregoing problems experienced with or shortcomings of cathode ray tubes are exacerbated as the size of the viewing screen increases. Since the current trend, and in fact consumer demand, is toward larger screens; weight, breakability, placement, etc. represent significant commercial considerations. Accordingly, it should be apparent that cathode ray tubes are and will continue to be inappropriate for use those applications in which weight, fragility and portability are important factors.

One system which can eliminate all of the aforementioned shortcomings of the present day cathode ray tube is the flat panel liquid crystal display in which a matrix array of liquid crystal picture elements or pixels are arranged in a plurality of rows and columns. Liquid crystal displays may typically be either transflective or transmissive. A transflective display is a one which depends upon ambient light conditions in order to be viewed, i.e., light from the surrounding environment incident upon the side of the display facing the viewer is reflected back to the viewer. Differences in the orientation of the liquid crystal material housed within each liquid crystal pixel causes those pixels to appear either darkened or transparent. In this manner, a pattern of information is defined by the two dimensional matrix array of darkened (or transparent) pixels. However, and as should by now be apparent, transflective liquid crystal displays cannot be used in a dark or low light environment since there is no light available for reflection off the viewing surface of the display.

Conversely, transmissive liquid crystal displays require the use of illuminating means such as a lamp array operatively disposed on the side of the matrix array of picture elements opposite the viewer. This illumination means or backlight may further include a backreflector adapted to efficiently redirect any stray illumination towards the matrix array of rows and columns of picture elements, thus ensuring that the displayed image is as bright as possible (given the lighting capabilities and characteristics of the backlighting scheme being employed). The instant invention is specifically directed to this field of backlit, high resolution liquid crystal electronic displays.

The characteristics of the backlighting scheme are very important to both the quality of the image displayed by the matrix array of picture elements of the liquid crystal display and the profile, i.e., the thickness dimension, of that liquid crystal display. Accordingly, a great deal of the aforementioned research in the field of said electronic flat panel electronic displays has been dedicated to the design and fabrication of backlighting systems which optimize certain viewing and structural parameters of those flat panel displays. Characteristics which are acknowledged by experts as the most important in the design of optimized backlighting assemblies include; 1) uniformity over large surface areas of the light provided by the backlight over, i.e., the intensity of the light must be substantially the same at each pixel of the large area liquid crystal display; 2) very bright illumination provided by the backlight thus yielding a sharp, readily readable image to a remotely positioned viewing audience; 3) a low profile so that a flat panel liquid crystal display is substantially flat and can be operatively disposed for viewing without occupying an undue amount of the floor or counter space available in a room; 4) the overall design of the backlight which takes into consideration the number, configuration, and redundancy of lamps; 5) the heat effect caused by the number, configuration, redundancy and type of the lamps; and 6) the total power consumed by the lighting scheme which represents an extremely important consideration in hand held (portable) television units.

A number of different backlight configurations, all of which included a plurality of discrete optical components disposed between the plane of the source of backlit radiation and the plane of the matrix array of liquid crystal pixels, have been designed in an effort to maximize each of the desirable characteristics recited hereinabove. For example, those of ordinary skill in the art of liquid crystal display backlighting have attempted to use radiation diffusers in an effort to achieve a more uniform distribution of projected light across the entire viewing surface of the liquid crystal display. This technique, while useful for improving the uniformity of projected light, deleteriously effected the intensity of that projected light (said light appearing soft or washed-out. Thus, additional lamps were required when such radiation diffusers were employed, resulting in an increased heating effect upon the display. Further, due to the fact that such radiation diffusers were, of necessity, positioned an operative distance from both the source of backlighting as well as from the matrix array of liquid

crystal pixels, the depth dimension or profile of the electronic, flat panel display was significantly increased.

A second technique employed to enhance the quality of the backlight (and hence the quality of the displayed image) is to operatively dispose a light collimating lens, such as a fresnel lens, between the source of the backlight and the matrix array of liquid crystal picture elements. This design expedient has the effect of producing an intense, sharp image from a minimal number of lamps, while simultaneously providing a high degree of uniformity of projected radiation across the entire viewing surface of even large area displays. However, due to the nature of collimated light, the viewing angle of a display equipped with such a light collimating lens is limited. Indeed, viewing of the displayed image is impossible from any angle other than directly straight-on. Accordingly, a backlit display which employs only a light collimator without a mechanism for increasing the viewing angle has limited commercial applicability, and is wholly inappropriate for the gigantic markets related to television and computer monitors. Additionally, collimating means, such as fresnel lenses, are characterized by an operative focal length. (The focal length is that distance from the light source at which said lens must be disposed in order to properly collimate light emanating from said light source.) Thus, the light collimator has the undesirable effect of increasing the profile of the liquid crystal display. Also, backreflectors are inappropriate for use with light collimating. This is because light reflected therefrom does not originate from a position which is at the focal length of the collimating lens. Hence, light reflected from said backreflector will not be collimated. This results in localized bright spots on the surface of large area displays, degrading the quality of the displayed image.

In an effort to achieve the advantages of both light collimation and light diffusion, routineers in the backlit, flat panel liquid crystal display art have attempted to incorporate both a discrete light diffuser and a discrete light collimator into the same backlit liquid crystal display. Optically speaking, the results have been satisfactory only to the extent that the quality of the displayed image is relatively sharp, intense and uniform; while said image is visible over a relatively wide viewing angle. However, in order to maximize the optical effect of utilizing the diffuser-collimator combination, it was necessary to operatively space the collimator from the source of backlighting radiation, and then to space the diffuser from both the plane of the collimator and the plane of the matrix array of liquid crystal pixels. The result was a substantial increase in the profile, i.e., the depth dimension of the liquid crystal display. Indeed, in typical liquid low profile crystal display systems which include both a light collimator and a light diffuser, the distance from the light source to the diffuser is approximately 17 millimeters. This is to be compared to liquid crystal display systems including the diffuser/collimator lens of the instant invention wherein the distance from the light source is approximately 6 millimeters. It can thus be seen that by including both diffusing and collimating optical components, the profile of a typical flat panel liquid crystal display is significantly increased, thus eliminating one of the principle advantages of liquid crystal display systems; i.e., compactness.

Accordingly, it may be appreciated that there exists a need in the flat panel liquid crystal display art to provide an optical system for use with a backlit, flat panel liquid crystal electronic display which provides a bright, uniform image of high contrast and capable of being viewed over a wide viewing angle, while maintaining a narrow profile.

BRIEF SUMMARY OF THE INVENTION

There is disclosed herein an improved backlit electronic display and specifically a liquid crystal display adapted to provide an image to one or more remotely positioned observers. The improved liquid crystal display is defined by a matrix array of rows and columns of liquid crystal picture elements spacedly disposed from one side of a light source, means for diffusing light emanating from the light source, said diffusing means operatively disposed between said light source and said rows and columns of liquid crystal picture elements, and means for collimating light operatively disposed between said diffusing means and said light source. The improvement in the display of the instant invention residing in the fact that the diffusing means and the collimating means are integrally formed so as to define a unitary diffusing/collimating lens, whereby a bright and uniform distribution of light is provided in a low profile assembly.

The display preferably includes a back reflector which is operatively disposed on the side of the light source opposite the diffusing/collimating lens. In one preferred embodiment, the light source is configured as a single, elongated, serpentined, tubular lamp. In a second, equally preferred embodiment, the light source may be configured as a plurality of discrete tubular lamps, said lamps defining a given lighting configuration. Regardless of whether the light source defines a lighting configuration formed of a single elongated tubular lamp or a plurality of discrete lamps, said diffusing/collimating lens will comprise a multi-lobed, coplanar lens array.

In the case where the serpentined pattern of the tubular lamp array is defined by a single elongated tubular lamp array disposed in a random pattern, the configuration of the multi-lobed diffusing/collimating lens array is substantially identical to the configuration of the random pattern of that tubular lamp array. Alternatively, the serpentined configuration may be defined by a series of generally parallel, elongated, longitudinal axes of the lamps and the multi-lobed coplanar lens array is operatively positioned on the same side of the light source as the matrix array of liquid crystal picture elements so that each coplanar lobe of the array is associated with a corresponding one of the plurality of parallel lamp axes.

In the case where the serpentined pattern of the tubular lamp array is defined by a plurality of tubular lamps, the configuration of the multi-lobed diffusing/collimating lens array is substantially identical to the configuration of the random pattern defined by the discrete lamps. Alternatively, the discrete tubular lamps may be defined by a series of generally parallel elongated longitudinal axes of the lamps and the muti-lobed coplanar lens array is operatively positioned on the same side of the light source as the matrix array so that each coplanar lobe is associated with a corresponding one of the plurality of parallel lamp axes.

The diffusing/collimating lens is characterized by a given focal length and the diffusing/collimating lens is positioned a distance from the light source which is substantially equal to that focal length. Importantly, the material from which the diffusing/collimating lens is fabricated is translucent so as to uniformly diffuse light

passing through the diffusing/collimating lens to the matrix array of liquid crystal picture elements. More particularly, the translucent material from which the diffusing/collimating lens is fabricated comprises bead-like elements suspended in a binder. In one preferred embodiment of the invention, the bead-like elements are formed of glass, are of a substantially spherical shape with a diameter of about one-to-one hundred micrometers, preferably a diameter of about three-to-seventy micrometers, and the binder is a polyurethane epoxy resin. In an alternate preferred embodiment, the bead-like elements are formed of a synthetic plastic resin. The critical factor, however is not in the material from which the beads are formed, but rather, the critical factor resides in forming the beads and the binder from materials which are characterized by different indices of refraction. More particularly, a typical index of refraction for the beads is about 1.6 and a typical index of refraction for the binder is about 1.5. Finally, it is preferred that the diffuser/collimator lens be fabricated of a synthetic plastic resin so that said lens can be readily molded to conform to the shape of the lobes of the lamp array operatively disposed therebelow.

It must be emphasized that the improved backlighting arrangement of the instant invention will operate with equal effectiveness in passive displays as well as in active matrix electronic displays. In such active matrix liquid crystal displays, each picture element will include a pair of electrodes having liquid crystal material operatively disposed therebetween and at least one threshold device. Where two threshold devices are employed, they are electrically coupled together at a common node in non-opposing series relationship. The threshold devices preferably comprise diodes formed from deposited thin film layers of amorphous silicon alloy material of p-i-n construction.

These and other objects and advantages of the instant invention will become apparent to the reader from a perusal of the Detailed Description Of The Invention, the Drawings and the Claims, all of which follow immediately hereinafter.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a stylistic front elevational view of the matrix array of rows and columns of liquid crystal picture elements of the active matrix embodiment of the electronic display of the instant invention schematically illustrating the manner in which the threshold switching elements are operatively disposed between the address lines and one of the picture element electrodes;

FIG. 2 is an equivalent circuit diagram, as disposed in the active matrix embodiment of the array of FIG. 1, illustrating the relationship between the liquid crystal picture elements and the anode-to-cathode connected diodes by which individual ones of the picture elements schematically depicted in FIG. 1 are addressed;

FIG. 3 is a fragmentary perspective view illustrating the relative disposition of one preferred embodiment of the diffusing/collimating lens array of the instant invention relative to a first embodiment of an axially aligned array of tubular lamps;

FIG. 4 is a fragmentary perspective view illustrating the relative disposition of a second preferred embodiment of the diffusing/collimating lens array of the instant invention relative to a random array of tubular lamps; and

FIG. 5 is cross-sectional view taken along line 5—5 of FIG. 3 and illustrating the manner in which rays of light emanating from the axially aligned lighting configuration of FIG. 3 are split and collimated by the optical media of the diffusing/collimating lens array of the instant invention.

DETAILED DESCRIPTION OF THE INVENTION

Disclosed as part of the instant invention is an improved backlighting assembly for an electronic display, such as a liquid crystal display and most specifically, by way of example and not by way of limitation, to an active matrix liquid crystal display. It is to be specifically noted that while an active matrix liquid crystal display will be described in detail hereinafter as a preferred embodiment, the instant invention can be used with equal advantage in any type of backlit electronic display known to routineers in the art. Therefore, the improved backlighting assembly described herein is adapted to enhance lighting parameters such as brightness, redundancy of lamps, low heat effects, while simultaneously providing a low profile (as defined hereinafter) to the overall depth dimension of the display structure. With the foregoing objectives clearly in mind, the improved assembly can now be described in greater detail.

Referring now to FIG. 1, there is depicted therein a matrix array of rows and columns of discrete liquid crystal display picture elements, said matrix array being generally designated by the reference numeral 10. Each liquid crystal display picture element, or pixel, 12 includes two spacedly disposed pixel electrode plates with a light influencing material, such as a liquid crystal composition, operatively captured therebetween. (The electrode plates and the light influencing material will be discussed in detail with respect to FIG. 3.) Each of the pixels 12 further includes a threshold switching device or a plurality of threshold switching devices for selectively applying an electric field across the liquid crystal composition when the electric field exceeds a predetermined threshold value.

More specifically, the matrix array 10 which defines the liquid crystal display of the instant invention includes a first set of X address lines 20, 22 and 24; a second set of Y address lines 26, 28 and 30; and a plurality liquid crystal picture elements 32, 34, 36, 38, 40, 42, 44, 46 and 48. The display further includes at least one isolation or addressing element 50, 52, 54, 56, 58, 60, 62, 64 and 66 operatively associated with and electrically connected to each respective one of the picture elements. As should be readily apparent to the reader from even a cursory review of FIG. 1, the X address lines 20, 22 and 24 and the Y address lines 26, 28 and 30 cross over one another at an angle so as to define a plurality of spaced crossover points associated with respective ones of the liquid crystal picture elements 32–48. The picture elements are formed on a transparent substrate, such as glass, and are distributed thereover in spacedly disposed relation so as to define interstitial spaces therebetween.

As can be ascertained from a perusal of FIGS. 1 and 2, each of the threshold devices 50–66 is preferably coupled in non-opposing series relation with a first one of the pixel electrodes. This type of switching arrangement will now be described in greater detail with respect to FIG. 2. In FIG. 2, the matrix array 10, includes a plurality of substantially parallel address line pairs 20, 20′, 22, 22′, 24 and 24′ which are the row select lines and a plurality of substantially parallel column address lines

26 and 28. The column address lines 26, 28, and 30 cross the row select address line pairs at an angle and are spaced from the row select address line pairs to form a plurality of crossover points therewith. Preferably, the column address lines cross the row select line pairs at an angle which is substantially perpendicular thereto.

Since, as mentioned hereinabove, each of the pixels are identical, only pixel 12 will be described in detail in the following paragraphs. Pixel 12, as can be seen from the figures, includes a pair of threshold devices 74 and 76 which are electrically coupled together at common node 78. The threshold devices 74 and 76 are preferably diodes and are electrically coupled together in non-opposing series relationship between the row select address line pair 20 and 20'. Although the threshold devices, in accordance with the preferred embodiment of the invention are diodes, said devices can be of any type which provides a high impedance to current flow when reverse biased and a comparatively low impedance to current flow when forward biased. Therefore, any bidirectional threshold switch or field effect transistor can be utilized with equal advantage. Of course, more conventional electrical interconnections would be employed with field effect transistors.

The picture element or pixel 12 further includes a pair of electrode plates 80 and 82 which are spaced apart and facing one another. Operatively disposed in the space between the electrodes 80 and 82 is a light influencing material 84. The term "light influencing material" is defined and will be used herein to include any material which emits light or can be used to selectively vary the intensity, phase, or polarization of light either being reflected from or transmitted through the material. In accordance with the preferred embodiment of the invention, the light influencing material is a liquid crystal display material, such as a nematic liquid crystal material. In any event, the electrodes 80 and 82 with the liquid crystal material 84 disposed therebetween form a storage element 86 (or capacitor) in which electric charge can be stored. As illustrated, the storage element 86 is coupled between the common node 78, formed by the electrically connected diodes 74 and 76, and the column address line 26.

Still referring to FIG. 2, the display 10 further includes a row select driver 50 having outputs R-1a, R-1b, R-2a, R-2b, R-3a, and R-3b electrically coupled to the row select line pairs 20, 20', 22, 22', 24, and 24'. The row select driver 50 provides drive signals at the outputs thereof to apply first operating potentials which are substantially equal in magnitude and opposite in polarity between the row select address line pairs to forward bias the threshold devices to in turn facilitate the storage of electric charge in the storage elements coupled thereto. The row select driver also applies second operating potentials which are substantially equal in magnitude and opposite in polarity between the row select address line pairs to reverse bias the threshold devices to facilitate the retention of the electric charge stored in the storage elements coupled thereto.

Lastly, the electronic display 10 includes a column driver 92. The column driver 92 includes a plurality of outputs, C1 and C2, which are coupled to the column address lines 26 and 28 respectively. The column driver is adapted to apply a charging potential to selected ones of the column address lines for providing electric charge to be stored in selected storage elements during the application of the first operating potentials to the row select address line pairs by the row select driver 50.

It is preferred that the matrix array of rows and columns of picture elements that combine to make up the improved electronic display 10 of the instant invention utilize a "balanced drive" scheme for addressing each discrete one of the pixels thereof. In this driving scheme, the operating potentials applied to the row select address line pairs are always substantially equal but opposite in polarity. Assuming that the current-voltage characteristics of each of the diodes are substantially equal, a voltage of substantially zero volts will be maintained at the common node 78, at least when the diodes are forward biased. Thus, the voltage applied on the column address line 26 to charge storage element 86 no longer needs to take into account the voltage drop across and/or parasitic charge build-up on one or both of the diodes 74 and 76. Therefore, each pixel in the matrix array of rows and columns may be charged to a known and repeatable value regardless of its position in that matrix array. This permits improved gray scale operation resulting in at least 15 levels of gray scale in large area active matrix displays of the twisted nematic liquid crystal type using normal fluorescent back illumination. The pixels can also be charged more rapidly since the retained charge in the diodes associated with each pixel when they are reverse biased need not be initially dissipated to charge the storage elements. This is because this charge is dissipated when the diodes are first forward biased. A complete description of this driving scheme can be found in U.S. Pat. No. 4,731,610 issued on Mar. 15, 1988 to Yair Baron et al and entitled Balanced Drive Electronic Matrix System And Method Of Operating The Same, the disclosure of which is incorporated herein by reference.

Turning now to FIG. 3, there is depicted in a fragmentary perspective view, one preferred embodiment of the instant invention. In this embodiment, the diffusing/collimating lens is operatively configured as a coplanar lens array and is disposed so as to provide for a low profile electronic display assembly 11. Before continuing with the detailed description of the preferred embodiment, it is essential to define the manner in which the phrase "low profile" is employed throughout this specification. In this regard, the reader should be aware of the fact that every flat panel electronic display, such as the active matrix liquid crystal type described herein, has a length, a width and a depth dimension. The length and width dimensions of the display are dependent upon the size of the desired viewing surface formed by the rows and columns of the liquid crystal picture elements and the resolution capabilities for fabricating those picture elements. The depth dimension of the display is especially important and is dependent on the type of lighting assembly, the material from which the threshold devices are fabricated, the on-board electronics, the multiplexing schemes, and most importantly, the optical arrangement by which light is diffused, collimated and transmitted to the viewing audience. It is, inter alia, the depth dimension of liquid crystal displays that has been significantly improved by the inventive concept set forth herein and it is the reduction in that depth dimension, from about 17 millimeters between the lamp array and the diffusing/collimating lens to about 6 millimeters therebetween, which has been and will continue to be referred to as "low profile".

There are four basic elements which combine to form the electronic display 11 depicted in FIG. 3. The uppermost element is the generally rectangularly-shaped

glass panel 10 upon which the rows and columns of active matrix liquid crystal picture elements as well as the associated drive circuitry, described in the preceding paragraphs, are disposed. The lowermost element is the thin, generally rectangularly-shaped back reflector panel 98 upon the interior surface of which one or more thin film layers of highly reflective material, such as aluminum or silver and a light transparent material having a low index of refraction, are deposited. Disposed immediately above the highly reflective panel 98 is an array of light sources 100 from which radiation emanates and either passes directly towards the matrix array of picture elements or is reflected off of the highly reflective panel and then passes upwardly toward said matrix array. Finally, the improved diffusing/collimating lens 102 of the instant invention is operatively located between the array of light sources 100 and the matrix array of picture elements 10. It is the combination of these four elements which define the profile, preferably the low profile, of the electronic display of the instant invention.

More specifically, it is important to note that lighting is one of the critical parameters which is employed in assessing the visual appearance of a liquid crystal display. Not only is it essential that the image of the display appear clear and bright to the viewers thereof, but it is also important that the image be substantially as clear to viewers disposed at an angle relative to the vertical plane of the viewing screen of the display. The structural and optical relationship existing between the array of light sources and the diffusing/collimating lens helps to determine the clarity and viewing angle of the display. Accordingly, these two major components will be now described in greater detail.

In the preferred embodiment of the invention illustrated in FIG. 3, the array of light sources 100 is configured as one elongated, serpentined fluorescent lamp (although it must be appreciated that a plurality of discrete lamps could be employed without departing from the spirit or scope of the instant invention) arranged in a specific pattern or lighting configuration and having each section of lamp disposed in a generally horizontal plane. More specifically, the array, regardless of configuration, will be arranged to uniformly distribute radiation emanating therefrom over the entire surface area of the matrix of rows and columns of picture elements. To this end, the lighting array is shaped in a serpentined pattern which may include a plurality of elongated lamps, such as 100a–100e, each lamp of which has a longitudinal axis parallel to the longitudinal axis of the other major lamp sections. The length of each longitudinal lamp axis is generally coextensive with the length dimension of the matrix array of picture elements. The configuration of the lighting array 100 also includes curved end sections, such as 101c–101d. The number of the elongated axial sections of the lamps and the number of the curved end sections of the lamps must be sufficient to bathe the entire width dimension of the matrix array of picture elements with a uniform shower of illumination.

The diffusing/collimating lens 102 is formed as an integral unit, vis-a-vis, prior art diffusers and collimators which were formed as two distinct elements. The integrally formed diffusing/collimating lens is a multi-lobed, generally coplanar lens array, the configuration of which is selected to substantially match the configuration of the random pattern defined by the serpentined array of fluorescent lamps. The reader will of course realize that the multiple "lobes" 102a–102e of the diffusing/collimating lens 102 of this invention are configured and operatively located so as to be substantially identical to the shape of the curved surfaces of the elongated longitudinal axes of the tubular lighting array 100. The multi-lobed, coplanar lens array 102 is positioned on the same side of the light source 100 as the matrix array of picture elements so that each coplanar lobe is associated with a respective one of the plurality of elongated, parallel, longitudinally extending lamp sections.

The integrally formed diffusing/collimating lens 102 is fabricated from a translucent material, the purpose of which is to diffuse light emanating from the array of lamps and passing either directly or via the reflector through said lens 102. More particularly, in the preferred embodiment of the invention, the transluscent material is a synthetic plastic resin and comprises bead-like elements 103 disposed in an epoxy suspension. The bead-like elements are preferably formed of glass or plastic and have a generally spherical shape. The spherical beads are preferably formed so as to have a diameter of about 1 to 100 micrometers, more preferably a diameter of about 3 to 70 micrometers, and most preferably a diameter of about 5 to 50 micrometers. It is to be noted that the epoxy suspension, from which the translucent diffusing/collimating lens 102 is fabricated, is a u.v. curable polyurethane epoxy resin system which can be purchased from Conap Corporation under the trademark Conaphane UC-32. Due to the fact that the diffusing/collimating lens 102 is fabricated of a plastic resin, the shape thereof may be readily molded to substantially match the configuration of the lobes of the array of lamps disposed immediately therebelow.

While the beads may be fabricated from almost any glass or plastic resin known to those skilled in the art and the binder may likewise be fabricated from those epoxy resins known to those skilled in the art, it is critical that the respective index of refraction of the beads and the epoxy binder differ from one another. While it is necessary to be limited to any precise values, in the preferred embodiment of the invention, the index of refraction of the beads is chosen to be about 1.6 and the index of refraction of the epoxy binder is selected to be about 1.5.

The transluscent material, as employed in the environment of the instant invention, provides numerous advantages and a synergy of advantageous features for a backlit electronic display. Of course, this synergy of features requires that the diffusing/collimating lens be configured in substantially the same coplanar, multi-lobed shape as the random lighting configuration of the array of light sources. When so configured and fabricated, the diffusing/collimating lens serves as both a light collimating lens and as a light diffusing media. The collimating effect is obtained by positioning the lobes of the lens so that the focal length thereof is at the corresponding lamp location. Simultaneously, the optical effect occurs at the air-to-material interface. And, of course, the transluscent material from which the diffusing/collimating lens is fabricated diffuses light so as to uniformly distribute light emanating from said lamps in all directions for uniformly illuminating the entire viewing screen of the electronic display.

Turning now to FIG. 4, there is illustrated therein, by the reference numeral 11' a fragmentary perspective view of a second preferred embodiment of the diffusing-/collimating lens array 102' of the instant invention, said lens array being operatively disposed in spaced relation

to a lighting configuration 100' which is characterized by the array of lamps thereof formed as an elongated spiral. Aside from the configuration of the spiral lamps, and the corresponding configuration of the diffusing-/collimating lens array, the function, the operation and the relative location of the respective components of the electronic display 11' remain identical to the function, the operation and the disposition of the display components described hereinabove with respect to FIG. 3.

There are four basic elements which combine to form the electronic display depicted in FIG. 4. The uppermost element 10 is the rectangularly-shaped glass panel upon which the rows and columns of picture elements and drive circuitry are disposed. The lowermost element is the rectangularly shaped back reflector panel 98 upon the interior surface of which one or more highly reflective layers are deposited. Disposed above the reflective panel 98 is the array of light sources 100' adapted to generate and transmit a uniform body of radiation to and through the matrix array. Finally, a second embodiment of the improved diffusing/collimating lens 102' is located between the lamp array and the matrix array of picture elements.

In contrast to the configuration of the array of light sources 100 illustrated in FIG. 3, the serpentined array of lamps 100' depicted in FIG. 4 is generally shaped as a spiral or helical configuration. The purpose of illustrating such a configuration is to demonstrate to the reader hereof that the improvement described in the instant specification is not limited to any specific shape of elongated lamps, but can be employed with any lighting arrangement which will provide a high level of illumination over the entire surface area of the large area viewing screen of the electronic display. The point which is important to note however is that there must exist a correspondence in shape between that of the lighting configuration and that of the diffusing/collimating lens array. In other words, in the FIG. 4 embodiment of the instant invention, the lobes of the multi-lobed diffusing/collimating lens correspond to the shape and the disposition of the cylindrically shaped, helically arrayed lamps which are situated therebeneath. In this manner, the focal length of the diffusing-/collimating lens will be optimally spaced from the corresponding source of radiation to collimate light across the viewing screen.

Turning now to FIG. 5, there is depicted therein a cross-sectional view taken along line 5-5 of FIG. 3, said cross-sectional view provided to demonstrate the manner in which rays of light "r" emanating from the lamps 100*b*-100*c* of the lighting configuration 100 are collimated to present a sharp image to the viewing audience of the liquid crystal display of the instant invention. More particularly, there is depicted a plurality of lamps, such as 101*b*, 101*c*, and 101*d*, of the embodiment of the lighting configuration wherein the longitudinal axes thereof are disposed in substantially parallel alignment. As can be seen from a perusal of FIG. 5, the rays of light "r" emanating from the three parallel, but spacedly disposed lamps are directed upwardly through the relatively thin diffusing/collimating lens 102. At both the planar air-to-material interface 102*x* and the lobed material-to-air interface 102*y* thereof, the rays of light are collimated and transmitted to the viewers in that collimated fashion. Note that for purposes of illustrating the collimating effect of the multi-lobed lens array of the instant invention, neither the reflector plate 98 nor the matrix array 10 of rows and columns of liquid crystal picture elements are depicted in FIG. 5. Further, and also so as not to detract from the description of the collimating effect, the optical media from which the diffusing/collimating lens is fabricated has not been shown to include the spherically-shaped glass beads 103. Also in this regard, the reader is no doubt aware of the fact that in FIG. 3 only two of the beads are illustrated, although it is to be understood that those beads are randomly dispersed throughout the thickness of the translucent epoxy binder material from which the diffusing/collimating lens is fabricated.

While the foregoing paragraphs have described the inventive concept set forth in the this specification, the instant inventors do not intend to have the disclosed invention limited by the detailed embodiments, drawings or description; rather, it is intended that the instant invention should only be limited by the scope of the claims which follow hereinafter, as well as all equivalents thereof which would be obvious to those routineers of ordinary skill in the art.

We claim:

1. In a backlit liquid crystal display which includes a source of light; a matrix array of rows and columns of liquid crystal picture elements spacedly disposed from one side of said light source; means for diffusing light emanating from the light source, said diffusing means operatively disposed between said light source and said rows and columns of liquid crystal picture elements; and means for collimating light, said collimating means operatively disposed between said diffusing means and said light source; said liquid crystal display capable of providing an image to a remotely positioned observer; the improvement comprising, in combination:

said diffusing means and said collimating means forming an integral diffusing/collimating lens, which integral diffusing/collimating lens comprises a multi-lobed coplanar lens array fabricated from a transluscent material including bead-like elements with an index of refraction of about 1.6 disposed in a binder suspension having an index of refraction of about 1.5, whereby a bright, uniform, light distribution is provided in a low profile assembly.

2. A display as in claim 1, further including a backreflector operatively disposed on the side of said light source opposite said diffusing/collimating lens.

3. A display as in claim 1, wherein said light source is configured as a single, elongated, serpentined, tubular lamp.

4. A display as in claim 3, wherein the serpentined, tubular lamp configuration defines a random pattern, and wherein the configuration of the multi-lobed lens array is substantially identical to the configuration of the random pattern defined by the tubular lamp lighting configuration.

5. A display as in claim 3, wherein the serpentined lamp configuration defines a series of generally parallel, elongated lamps having generally parallel, elongated axes, and wherein the multi-lobed coplanar lens array is operatively positioned on the same side of the light source as the matrix array so that each coplanar lobe is associated with a corresponding elongated axis of the lamps.

6. A display as in claim 1, wherein said light source is configured as a plurality of discrete tubular lamps, said discrete lamps defining a lighting configuration.

7. A display as in claim 4, wherein the discrete, tubular lamps define a random pattern, and wherein the

configuration of the multi-lobed lens array is substantially identical to the configuration of the random pattern defined by the discrete lamp lighting configuration.

8. A display as in claim 4, wherein the discrete tubular lamp lighting configuration defines a series of generally parallel, elongated lamps having generally parallel, elongated axes, and wherein the multi-lobed coplanar lens array is operatively positioned on the same side of the light source as the matrix array so that each coplanar lobe is associated with a corresponding parallel axis of the lamps.

9. A display as in claim 1, wherein said diffusing/collimating lens is characterized by a focal length and said diffusing/collimating lens is positioned a distance from the light source which is substantially equal to said focal length.

10. A display as in claim 1, wherein the bead-like elements are glass.

11. A display as in claim 10, wherein said glass bead-like elements are spherically shaped.

12. A display as in claim 10, wherein said light diffusing glass beads have a diameter of at least about 1 to 100 micrometers.

13. A display as in claim 12, wherein the binder in which said spherically shaped glass bead-like elements are disposed is a translucent epoxy suspension.

14. A display as in claim 1, wherein the liquid crystal display is an active matrix liquid crystal display.

15. A display as in claim 1, wherein each liquid crystal picture element comprises a pair of electrodes having liquid crystal material disposed therebetween and at least one threshold device connected at one of the terminals thereof to one of said electrodes.

16. A display as in claim 15, wherein said at least one threshold device comprises a transistor formed from deposited layers of semiconductor material.

17. A display as in claim 15, wherein the threshold devices comprise diodes formed from deposited layers of semiconductor material.

18. A display as in claim 15 wherein a pair of threshold devices are provided, said threshold devices electrically coupled together at a common node in non-opposing series relationship.

19. A display as in claim 18, wherein the semiconductor material is an amorphous silicon alloy material.

* * * * *

Exhibit 15

Unexamined Utility Model S58-109786

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(54)	Title	Lighting Apparatus for a Display Panel
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SPECIFICATIONS

1. Title of the Concept

Lighting Apparatus for a Display Panel

2. Claims

(1) Lighting apparatus for a display panel characterized as being provided with light sources (1, 1′), Fresnel lenses (2, 2′, 2″, 2″′, 2″″) that create parallel beams of light from said light sources and diffusion plate (3) that diffuses the light from said Fresnel lenses, whereby display panel (4) is lighted by the light transmitted from said diffusion plate.

(2) The lighting apparatus for a display panel described in Claim 1 of the present utility model that is characterized in that light source (1) is a spheroidal light source and in that the lens surface-forming grooves of Fresnel lens (2) are shaped in the form of a concentric circle centered around spheroidal light source (1).

(3) The lighting apparatus for a display panel described in Claim 1 of the present utility model that is characterized in that light source (1′) is a cylindrical light source and in that the lens surface-forming grooves of Fresnel lens

(2′) form a straight parallel line in the lengthwise

direction of cylindrical light source (1′).

(4) The lighting apparatus for a display panel described in Claim 1 of the present utility model characterized in that aforementioned light source (1′) is a cylindrical light source and in that aforementioned Fresnel lens (2″) is comprised of first and second Fresnel lenses (2″a, 2″b) for which each of the lens surface-forming grooves form a straight parallel line in the lengthwise direction of said cylindrical light source (1′).

(5) The lighting apparatus for a display panel described in Claim 1 of the present utility model characterized in that aforementioned light source (1′) is a cylindrical light source and in that Fresnel lens (2″′) is comprised of first Fresnel lens (2″′a), whose lens surface-forming grooves form a straight parallel line in the lengthwise direction of said cylindrical light source (1′) and second Fresnel lens (2″′b) that has a lens surface-forming slit that forms a straight line that crosses orthogonally with the lens surface-forming grooves of said first Fresnel lens and that is arranged between said first Fresnel lens and display panel (4).

(6) The lighting apparatus for a display panel described in

Claims 1 through 5 of the present utility model characterized in that the center of the lens for said Fresnel lens (2″″)

together with light sources (1, 1') are set up in an eccentric position from the center of the display surface of display panel 4.

3. **Detailed Description of the Concept**

The present concept pertains to lighting apparatus for a display panel that is advantageous in transmitting light to various types of display panels, such as various gauge display panels, various types of working display panels and liquid crystal display panels.

In conventional lighting means used for transmitting light to the various types of display panels, a light bulb was placed on the backside of the display panel for the purpose of transmitting light. However, since lighting means that use light bulbs are point light sources, they cannot transmit light in uniform illumination for the entire surface of the display panel, and have therefore been problematic in that they have been defective in transmitting light in liquid crystal display panels, which particularly require uniform lighting. In order to resolve this problem, some conventional examples used a cylindrical fluorescent lamp or a plate-shaped fluorescent lamp, but although such conventional examples were an improvement over the

aforementioned lighting means that used light bulbs, they were problematic in that a perfect surface light source could not be obtained and they were also very costly. In addition, lighting means

using a two-dimensional light source such as an EL (Electro-luminescence) element have been proposed, but since EL lighting has a high drive voltage, an inverter is required in order to use it in display panels for automobiles, for example, resulting in higher installation costs and since the EL lighting mechanism itself is expensive, it becomes problematic from an economic standpoint.

The present concept provides a lighting apparatus for a display panel that solves these problems and it's main point is to arrange a Fresnel lens and a diffusion plate that diffuses the light transmitted from the Fresnel lens to the front of the light source so that the light from the light source is converted to parallel light beams by the Fresnel lens and the light beams are then diffused by means of the diffusion plate in order to provide a lighting apparatus for a display panel that can obtain transmitted light with consistent illumination.

The following is a detailed explanation of the drawings showing working examples of the present concept.

Working Example I

In Drawing 1, No. 1 is a light bulb, which is the spheroidal light source, and to the front of light source 1 is arranged Fresnel lens 2, which is comprised of multiple ring-shaped lens surface-forming grooves (hereafter referred to as Fresnel grooves) that form concentric circles placed in close proximity to one another. Also to the front of Fresnel lens 2 is placed diffusion plate 3. The lighting apparatus for the present working example consists of light source 1, Fresnel lens 2 and diffusion plate 3. No. 4 is a display panel, such as a liquid crystal display panel, that has been positioned in front of the lighting apparatus, or in other words, in front of diffusion plate 3. No. 5 is a light-inducing body with a reflective surface that induces the light from light source 1 that is not initially irradiated onto Fresnel lens 2 to the side at which said Fresnel lens is located, and although this light-inducing body is not a required component of the configuration, it's use can more efficiently irradiate the light from the light source to the Fresnel lens, which is also the case in the following working examples.

As described above, for the present working example, since Fresnel lens 2 and diffusion plate 3 are arranged consecutively in front of light source 1, the light that is emitted from light

source 1 is converted to parallel light beams by Fresnel lens 2 and the parallel light beams are then diffused by diffusion plate 3, so that lighting with even luminance can be obtained over the entire surface of diffusion plate 3. Although, for the present working example, one Fresnel lens is used for Fresnel lens 2, in such a case, it is effective if the space between light source 1 and Fresnel lens 2 is the focal distance for Fresnel lens 2. Furthermore, the configuration is not limited to the use of only one Fresnel lens and multiple Fresnel lenses may be used by adjusting the focal distance. In addition, by making diffusion plate 3 semi-transmittable, lighting can be achieved via a reflective type of liquid crystal display panel.

Working Example II

For this working example, in Drawing 2, instead of the spheroidal light source described in aforementioned Working Example I, a cylindrical fluorescent lamp is used as cylindrical light source 1′ and in addition, for Fresnel lens 2′, which should be arranged in front of light source 1′, multiple linear Fresnel

grooves are formed close together and parallel to the axial direction of light source 1′. Therefore, according to this working example, due to the operation of said Fresnel lens 2′, parallel light beams

are obtained in relation to the light that is in the direction of the diameter of light source 1′, thus achieving an almost uniform luminance over the entire surface of diffusion plate 3. However, since the light source used for this working example is a fluorescent lamp in which the amount of heat generated is extremely low, Fresnel lens 2′ can be placed near light source 1′, which is beneficial in that the entire lighting apparatus can be constructed of a very thin configuration.

Working Example III

For this working example, in Drawing 3, Fresnel lens 2″a and 2″b, which have the same Fresnel grooves as Fresnel lens 2′ described in Working Example II, are combined and placed between cylindrical light source 1′ and diffusion plate 3 to form Fresnel lens 2″. Therefore, according to this working example, since two Fresnel lenses, 2″a and 2″b, are used, the uniformity of the parallel light beams becomes favorable, resulting in improved consistency of the luminance of the surface light source.

Working Example IV

For this working example, in Drawing 4, Fresnel lens 2‴a, which has the same Fresnel grooves as Fresnel lens 2″a, described

in Working Example III, and Fresnel lens 2‴b, which has linear Fresnel grooves in close proximity to one another and that cross orthogonally with the Fresnel grooves for Fresnel lens 2‴a, are combined to form Fresnel lens 2‴, which is placed between cylindrical light source 1′ and diffusion plate 3. Therefore, according to this working example, since uniform parallel light beams are obtained in the vertical and horizontal directions, the uniformity of the luminance of the surface light source can be improved.

Working Example V

For this working example, in Drawing 5, since spheroidal light source 1 is arranged so as to avoid coming into contact with interior member 6, it must be placed so that it is eccentric with light source 1 in relation to the center of the Fresnel lens and diffusion plate. In this case, by using Fresnel lens 2⁗, which is formed from ring-shaped Fresnel grooves placed in close proximity to one another and which are eccentric with the center of the lens in accordance with the position of light source 1,
lighting that has a uniform luminance over the entire surface

of diffusion plate 3 can be obtained.

The aforementioned paragraphs have provided an explanation of each working example for the present concept. For each of the aforementioned working examples, if a diffusion lens were formed

on the surface opposite from the Fresnel grooves-forming surface of the Fresnel lens, aforementioned diffusion plate 3 could be eliminated and an even thinner construction could be achieved.

As described above, since the present concept pertains to a lighting apparatus for a display panel that is equipped with a light source, a Fresnel lens that creates parallel light beams from the light emitted from the light source and a diffusion plate that diffuses the light from said Fresnel lens for transmitting light from said diffusion plate to illuminate the display panel, and since it provides a construction whereby the light from a point light source or a line light source can be easily and quickly converted to a surface light source with uniform luminance, a lighting apparatus can be provided that is inexpensive and very economical. In addition, since the lighting apparatus that pertains to the present concept is constructed using a combination of a light source, Fresnel lens and a diffusion plate, a thinly- constructed lighting apparatus is also achieved.

4. Brief Description of the Drawings

Each of the drawings show working examples of the lighting apparatus that pertains to the present concept. Drawings 1(a) and 1(b) show a side view of Working Example I and a front view of the Fresnel lenses. Drawing 2 is a perspective view of Working Example II. Drawing 3 is a perspective view of Working Example III. Drawing

4 is a perspective view of Working Example IV. Drawings 5(a) and 5(b) are a cross-sectional explanatory diagram and a front view of the Fresnel lens for Working Example V.

1, 1'... Light source

2, 2', 2", 2"', 2"" ... Fresnel lenses

3 ... Diffusion plate 4 ... Display panel

5 ... Light-inducing body 6 ... Interior member

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Drawing 1

(a) (b)

Drawing 2

864

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Drawing 3

Drawing 4

865

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Drawing 5

(b)

(a)

866

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(54) 表示パネルの照明装置

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明細書

1. 考案の名称

表示パネルの照明装置

2. 実用新案登録請求の範囲

1 光源（1、1'）と該光源からの光を平行光線にするフレネルレンズ（2、2'、2"、2'''）と、該フレネルレンズからの光を拡散する拡散板（3）とを備え、該拡散板からの光で表示パネル（4）を透過照明してなることを特徴とする表示パネルの照明装置。

2 前記光源（1）は球状光源であり、かつ前記フレネルレンズ（2）はそのレンズ面形成用線が前記球状光源（1）を中心として同心円状であることを特徴とする実用新案登録請求の範囲第1項記載の表示パネルの照明装置。

3 前記光源（1'）は柱状光源であり、かつ前記フレネルレンズ（2'）はそのレンズ面形成用線が前記柱状光源（1'）の長手方向に平行な直線状であることを特徴とする実用新案登録請求

の範囲第1項記載の表示パネルの照明装置。

4 前記光源(1')は柱状光源であり、かつ前記フレネルレンズ(2'')は夫々のレンズ面形成用溝が前記柱状光源(1')の長手方向に平行な直線状である第1及び第2のフレネルレンズ(2''a、2''b)からなることを特徴とする実用新案登録請求の範囲第1項記載の表示パネルの照明装置。

5 前記光源(1')は柱状光源であり、かつ前記フレネルレンズ(2''')はレンズ面形成用溝が前記柱状光源(1')の長手方向に平行な直線状である第1のフレネルレンズ(2'''a)と、該第1のフレネルレンズのレンズ面形成用溝と直交する直線状のレンズ面形成用スリットを有し該第1のフレネルレンズと前記表示パネル(4)との間に配設される第2のフレネルレンズ(2'''b)とからなることを特徴とする実用新案登録請求の範囲第1項記載の表示パネルの照明装置。

6 前記フレネルレンズ(2''')のレンズ中心は前

記光源（1、1'）と共に前記表示パネル（4）の表示面中心から偏心した位置に設定されていることを特徴とする実用新案登録請求の範囲第1項乃至第5項記載の表示パネルの照明装置。

3. 考案の詳細な説明

本考案は、各種計器の表示パネル、ワーニング用の表示パネル、又は液晶表示パネル等の各種表示パネルを透過照明するに有利な表示パネルの照明装置に関するものである。

上記の各種表示パネルを透過照明するための従来の照明手段には、その表示パネルの裏側に電球を配置して、透過照明を行なうようにしたものがあつたが、この電球使用の照明手段では点光源となるために、表示パネルの全面に亘つて均一輝度の透過照明を行なうことができず、特に均一照明が要求される液晶表示パネルの透過照明には不適である問題点があつた。この問題点を解消するために棒状の螢光灯 あるいは板状の蛍光灯 を使用する従来例もあつたが、この従来例では前記電球使

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用の照明手段に比して改善はされるが、充分な照光源は得られず、その上コスト的にも高価となる問題点があつた。また平面光源であるEL(エレクトロルミネツセンス)素子を用いた照明手段も提案されているが、このEL照明は駆動電圧が高いために例えば自動車用表示パネルの照明手段として、このEL照明を使用するためにはインバータが必要となつて設備費が高くなり、更にはこのEL照明機構自体が高価であつて経済性の点で問題があつた。

本考案はかかる問題点を解決することのできる表示パネルの照明装置を提供するものであつて、その要旨とするところは、光源の前方に、フレネルレンズとこのフレネルレンズからの透過光を拡散する拡散板とを配置して、光源からの光をそのフレネルレンズにより平行光線に変換し、次いでこの光線を拡散板によつて均一に拡散せしめることにより、照明むらのない透過照明を得ることができる表示パネルの照明装置を提供することを目的とするものである。

以下に本考案を図面に示す実施例に基づいて詳細に説明する。

実施例1

第1図において、1は電球による球状光源であつて、この光源1の前方には多数のリング状のレンズ面形成用溝（以下フレネル溝という。）を同心的かつ等間隔で形成してなるフレネルレンズ2が配置されている。更にこのフレネルレンズ2の前方には拡散板3が配置され、これらの光源1、フレネルレンズ2、拡散板3によつて本実施例の照明装置が構成されている。4はこの照明装置の前方、即ち拡散板3の前方に位置せしめた例えば液晶表示パネル等の表示パネルである。5は光源1の光のうちそのままではフレネルレンズ2に照射しない光を該フレネルレンズ側に導く反射面を有する光導体であつて、この光導体は必須の構成要件ではないが、これを使用すれば光源からの光を効率よくフレネルレンズへ照射することができるものであり、以下の実施例でも同様である。

以上のように本実施例では、光源1の前方にフレネルレンズ2と拡散板3を順次配設したものであるから、その光源1より発した光が、そのフレネルレンズ2によつて平行光線に変換され、次いでこの平行光線が拡散板3によつて拡散されることから、その拡散板3の前面では、該拡散板3の全面に亘つて均一輝度の照明光が得られる。尚本実施例では一枚のフレネルレンズ2を使用しているが、この場合は光源1とフレネルレンズ2との間隔をフレネルレンズ2の焦点距離とするのが有効である。またこれには限らず複数枚のフレネルレンズを使用して、この焦点距離を調節してもよい。また前記の拡散板3を半透過形とすることにより液晶表示パネルを反射型でも照明できる特長がある。

実施例2

第2図において、本実施例は、上記第1の実施例における球状光源にかえ、柱状蛍光灯による柱状光源1'を使用し、更にこの光源1'の前方に配置すべきフレネルレンズ2'にはその光源1'

の幅方向と平行する多数の直線状フレネル溝が所定間隔で形成されているものである。従つて本実施例によれば、上記フレネルレンズ2'の作用により光源1'の径方向の光に対して平行光線が得られるので、拡散板3の全面に亘つて略均一輝度の照明光が得られるが、この実施例で使用する光源は、発熱量がきわめて少ない蛍光灯を使用しているために、この光源1'にフレネルレンズ2'を近接することもできるので、照明装置全体を薄型に形成することができる効果がある。

実施例Ⅲ

第3図において、本実施例は、上記の第2実施例におけるフレネルレンズ2'と同様のフレネル溝を有する2枚のフレネルレンズ2''aと2''bとを組合わせてなるフレネルレンズ2''を柱状光源1'と拡散板3との間に介在せしめたものである。従つて本実施例によれば、2枚のフレネルレンズ2''a、2''bを使用していることから、平行光線の均一性が良好になされ、面光源としての輝度の均一性が高められる効果がある。

公開実用 昭和58—109786

実施例IV

第4図において、本実施例は、上記の第3実施例におけるフレネルレンズ$2''a$同様のフレネル帯を有するフレネルレンズ$2'''a$と、このフレネルレンズ$2'''a$のフレネル帯の方向と直交する山形状フレネル帯を等間隔で形成したフレネルレンズ$2'''b$とを組合わせてなるフレネルレンズ$2'''$を柱状光源$1'$と拡散板3との間に使用したものである。従つて本実施例によれば、縦横方向に均一な平行光線が得られるために、面光源としての輝度の均一性が高められる。

実施例V

第5図において、本実施例は、内装部材6を避けて線状光源1を配置するためにフレネルレンズ及び拡散板の中心位置に対して光源1を偏心して配置しなければならない場合であつて、この場合はその光源1の位置に応じてレンズ中心が偏心されたリング状フレネル帯を等間隔で形成してなるフレネルレンズ$2''''$を使用することにより、拡散板3の表面では該拡散板3の全面

に亘つて均一輝度の照明光が得られる。

以上が本考案よりなる各実施例の説明であるが、上記いずれの実施例においても、フレネルレンズのフレネル溝形成面と反対側の面に拡散レンズを形成すれば上記の拡散板3を省くことができ更に薄型にできる。

以上のように本考案は光源と、該光源からの光を平行光線にするフレネルレンズと、該フレネルレンズからの光を拡散する拡散板とを備え、該拡散板からの光で表示パネルを透過照明するようにした表示パネルの照明装置であるから、点光源、あるいは線光源からの光を均一な輝度の面光源に変換することが容易かつ簡単な構造によつてなされることから、安価であつて経済性に優れた照明装置が提供できる。また本考案による照明装置は、光源、フレネルレンズ及び拡散板の組合わせによつて構成されることから薄型の照明装置が得られる効果もある。

4. 図面の簡単な説明

図面はいずれも本考案よりなる照明装置の実

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施例を示し、第1図(a)及び(b)はその第1実施例を示した側面図及びフレネルレンズの正面図、第2図は第2実施例の斜視図、第3図は第3実施例の斜視図、第4図は第4実施例の斜視図、第5図(a)及び(b)は第5実施例の断面説明図及びフレネルレンズの正面図である。

1、1'…光源

2、2'、2"、2'"、2""…フレネルレンズ

3…拡散板　　　　4…表示パネル

5…光導体　　　　6…内装部材。

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本　多　小　平

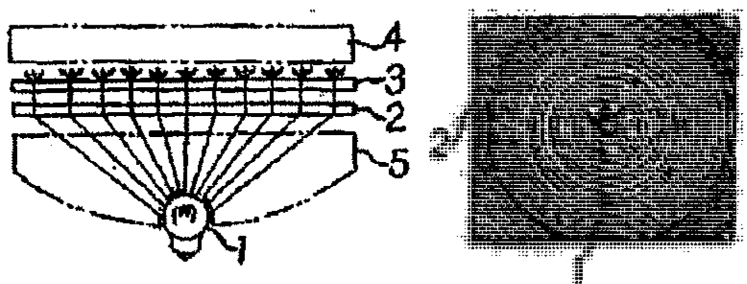
岸　田　正　行

新　部　興　治

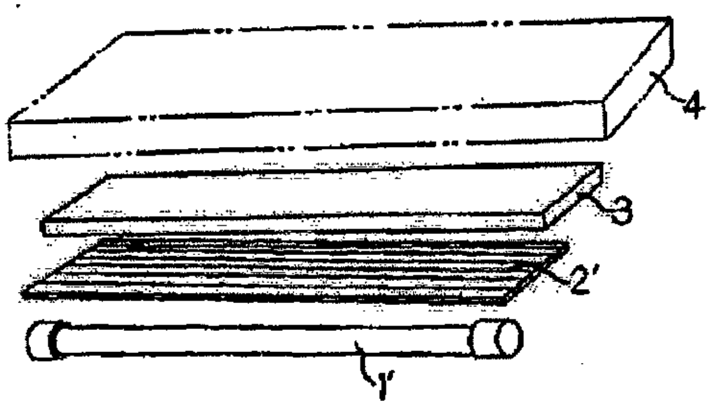
(10)

第1図

(a) (b)



第2図



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代理人 谷 山 [illegible] 他3名

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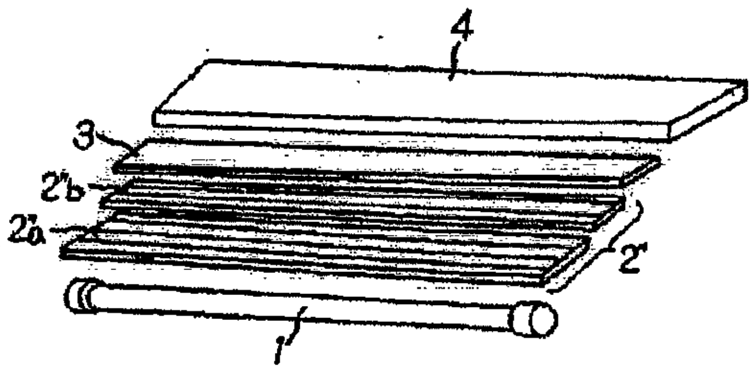
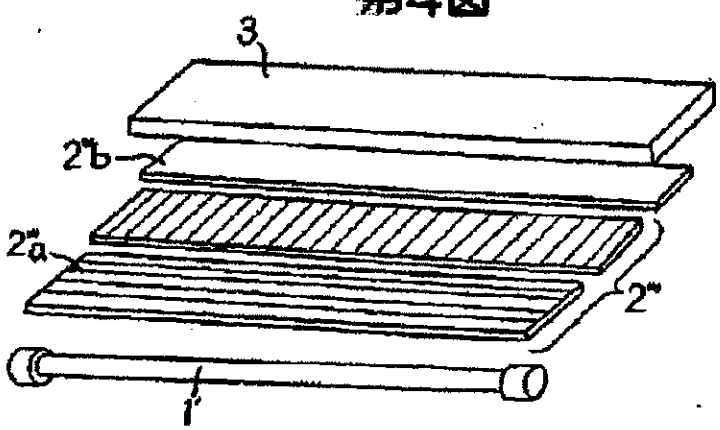
第3図



第4図



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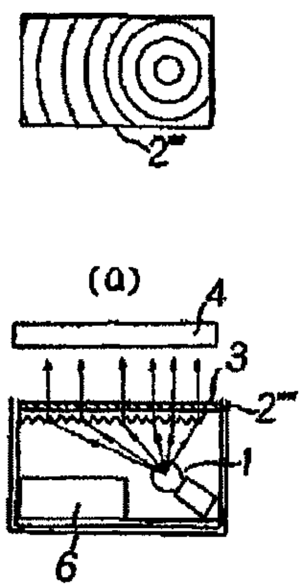
実開58-109786

代理人 谷山

第5図



866

実開58-109786

代理人 谷山 輝雄 外3名

Exhibit 16

US005126882A

United States Patent [19]

Oe et al.

[11] Patent Number: 5,126,882

[45] Date of Patent: Jun. 30, 1992

[54] PLANE LIGHT SOURCE UNIT

[75] Inventors: Makoto Oe; Ikuo Chiba, both of Tokyo, Japan

[73] Assignee: Mitsubishi Rayon Co., Ltd., Tokyo, Japan

[21] Appl. No.: 269,723

[22] Filed: Nov. 10, 1988

[30] Foreign Application Priority Data

Nov. 12, 1987 [JP] Japan 62-284289
Jun. 2, 1988 [JP] Japan 63-134393

[51] Int. Cl.[5] G02B 27/00; G02F 1/1335

[52] U.S. Cl. 359/619; 359/36; 359/40

[58] Field of Search 350/167, 330, 334, 338, 350/345

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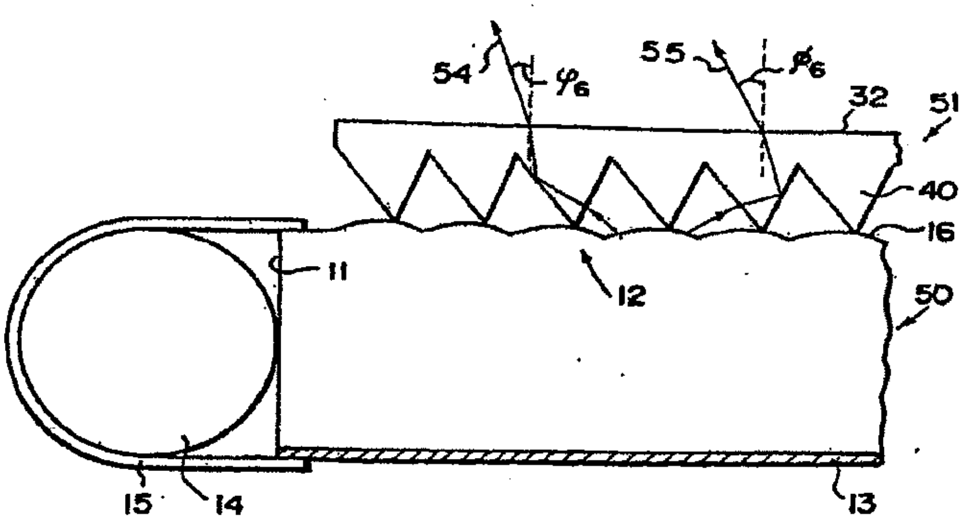
Primary Examiner—Paul M. Dzierzynski
Assistant Examiner—Hung Xuan Dang
Attorney, Agent, or Firm—Oblon, Spivak, McClelland, Maier & Neustadt

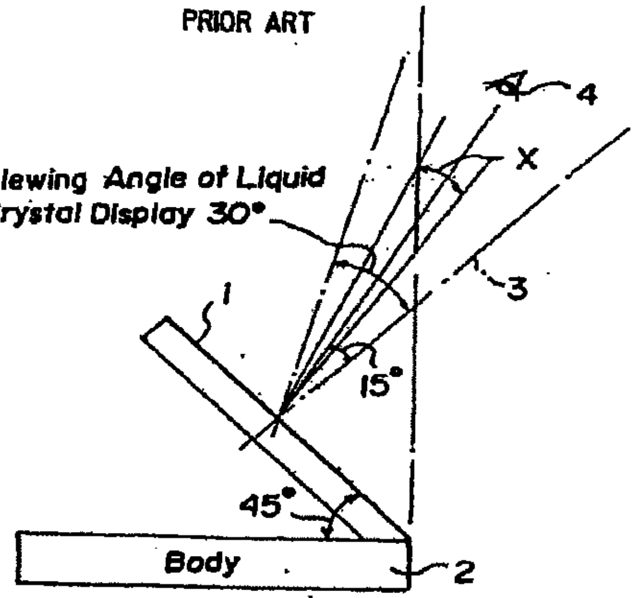
[57] ABSTRACT

A plane light source unit is provided which comprises a first element having a light incident face at least at one side end thereof and a first light emitting surface extending perpendicularly to the light incident face, the first element further having a reflecting layer provided on a surface thereof opposite to the first light emitting surface, and a second element having a light incident surface which receives the light emitted by the first element and a second light emitting surface through which light is emitted in a predetermined direction, the first light emitting surface and/or the opposite surface of the first element having a directive function to cause incident light through the light incident face to emit through the first light emitting surface in a direction oblique to the direction of the light, the second element having a large number of prism units formed on the light incident surface thereof. The plane light source unit is advantageously used as a backlighting means for a liquid crystal display device or the like.

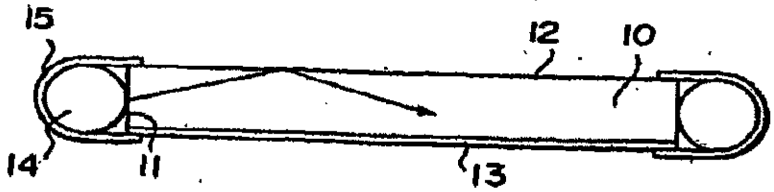
15 Claims, 34 Drawing Sheets



F I G. 1
PRIOR ART



F I G. 2 (a) PRIOR ART



F I G. 2 (b) PRIOR ART

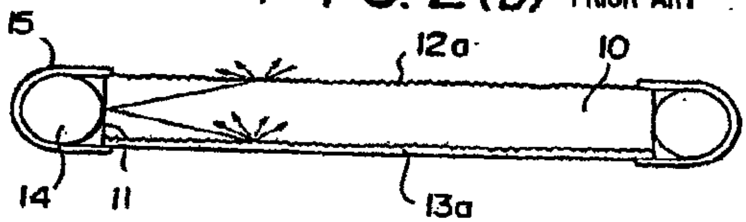
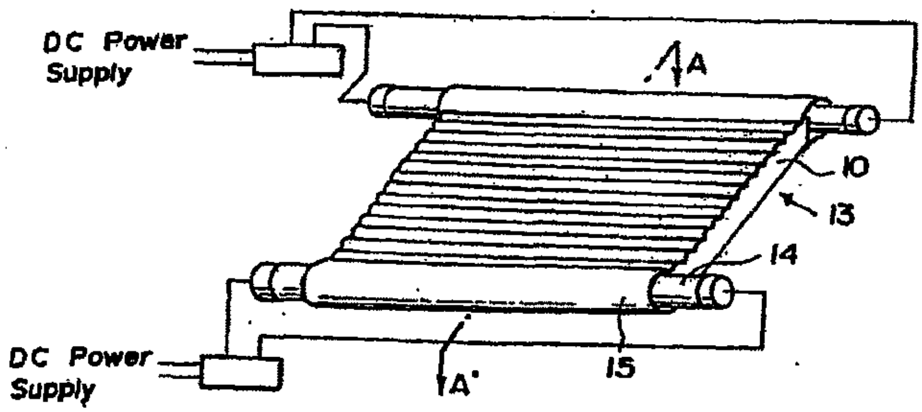


FIG. 3

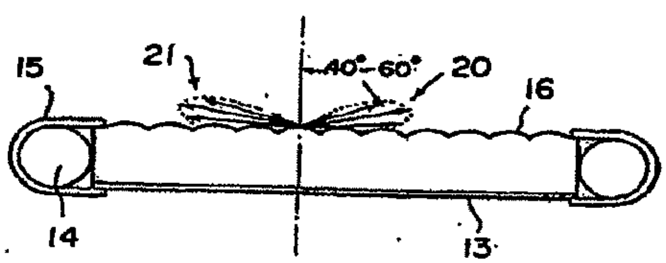
(a)



DC Power Supply
A
10
13
14
DC Power Supply
A'
15

FIG. 3

(b)



15
21
40°-60°
20
16
14
13

FIG.4

(a)

Central Point ①

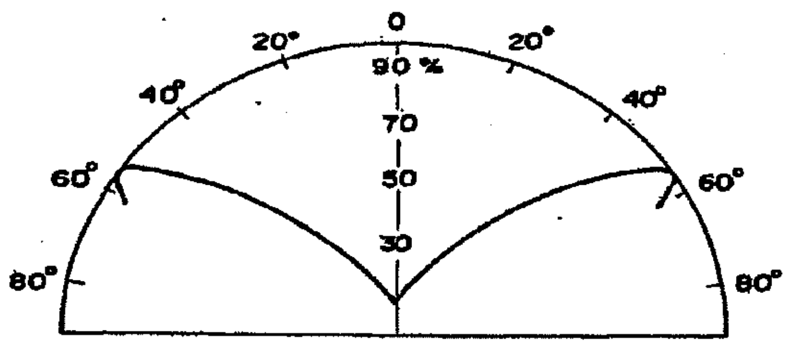


FIG.4

(b)

10mm Point ② from Lamp

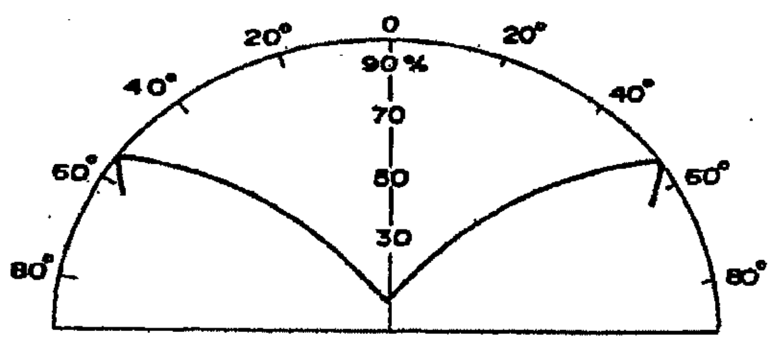


FIG. 5

(a)

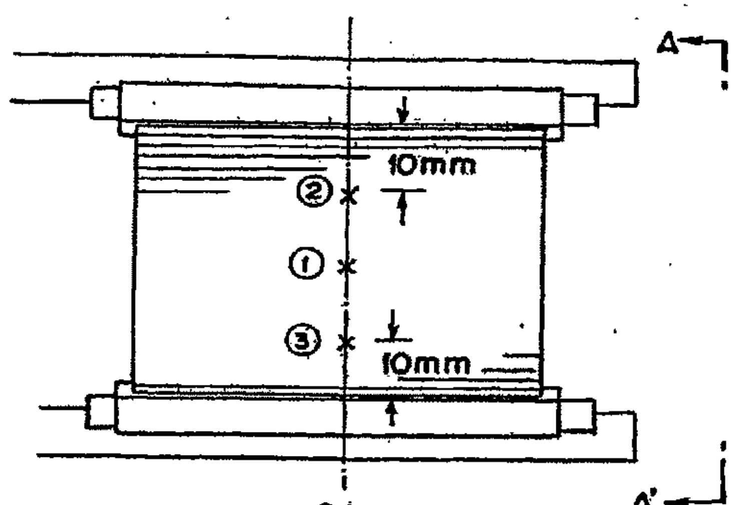


FIG. 5

(b)

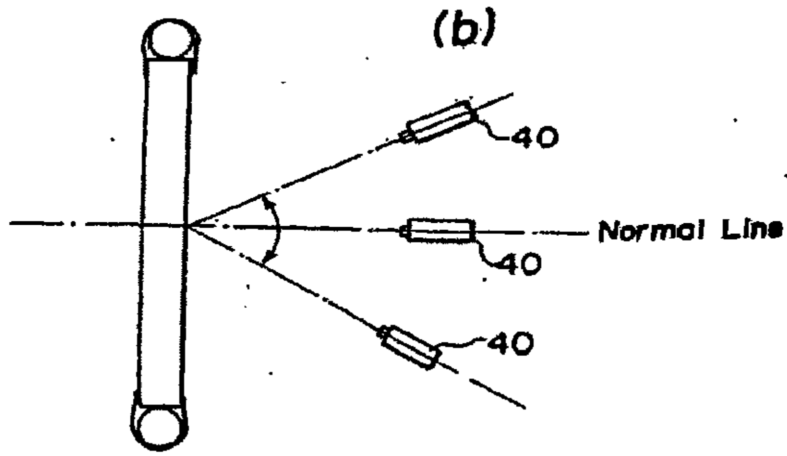


FIG. 6 (a)

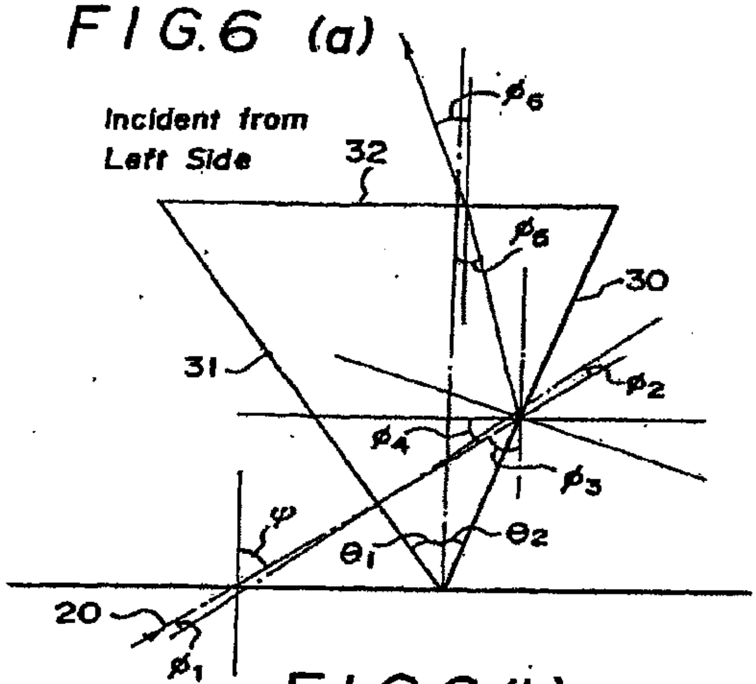

Incident from
Left Side
32
30
31
20
ψ
θ1
θ2

FIG. 6 (b)

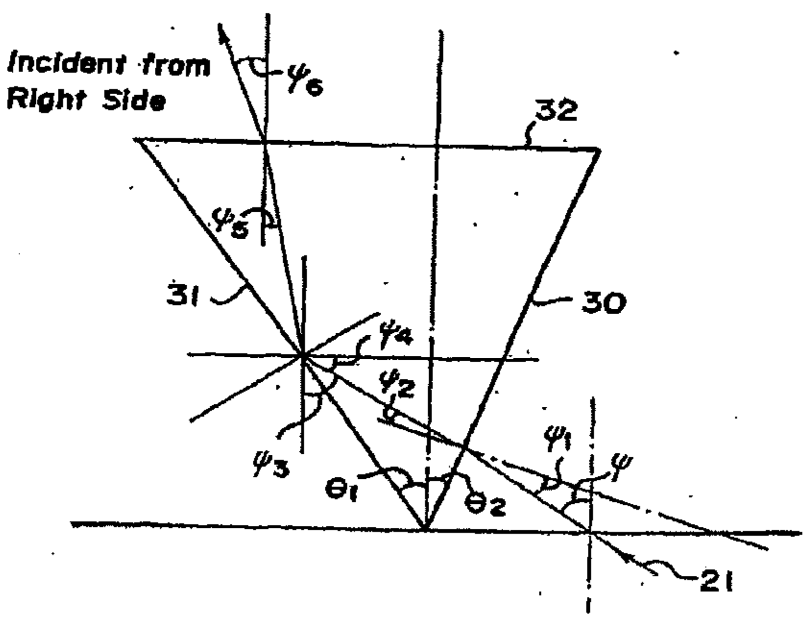
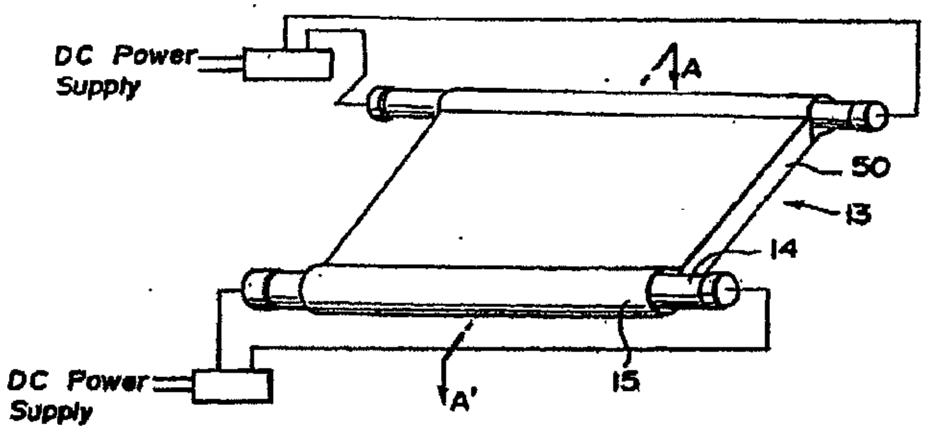
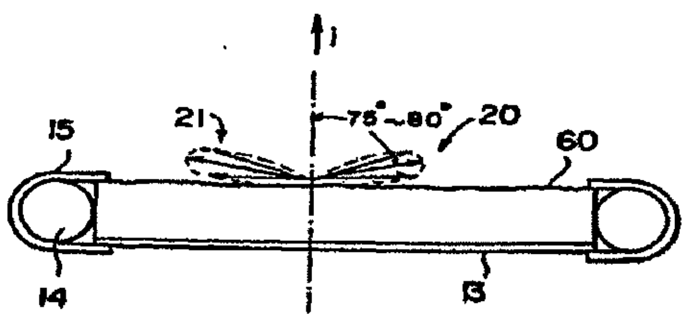

Incident from
Right Side
32
31
30
21
θ1
θ2

FIG. 7
(a)



DC Power Supply
A
50
13
14
DC Power Supply
A'
15

FIG. 7
(b)



I
21
75°~80°
20
15
60
14
13

FIG. 8
(a)

Sample-1 Haze 70.8 %

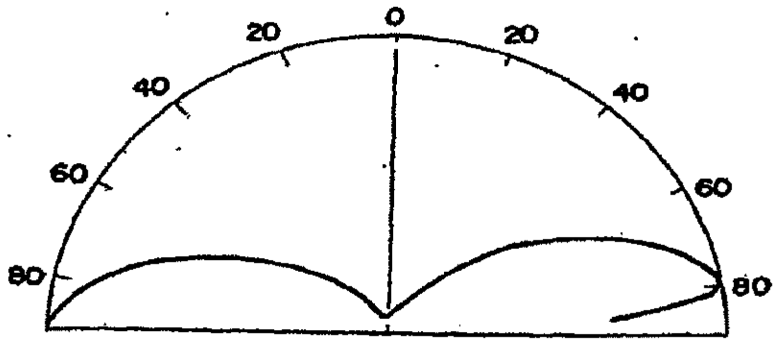


FIG. 8
(b)

Sample-2 Haze 64.8%

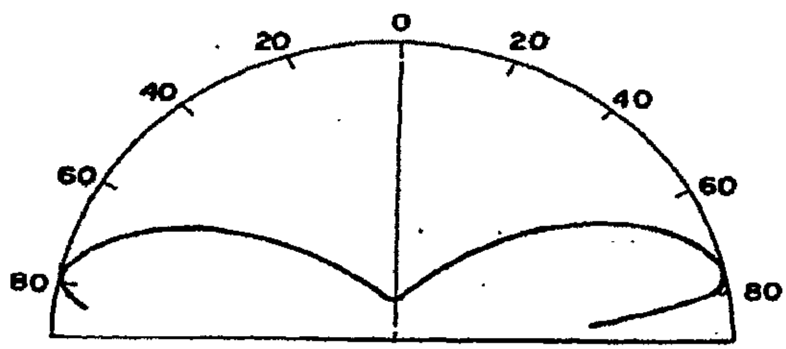


FIG. 8

(c)

Sample-3 Haze 40.8 %

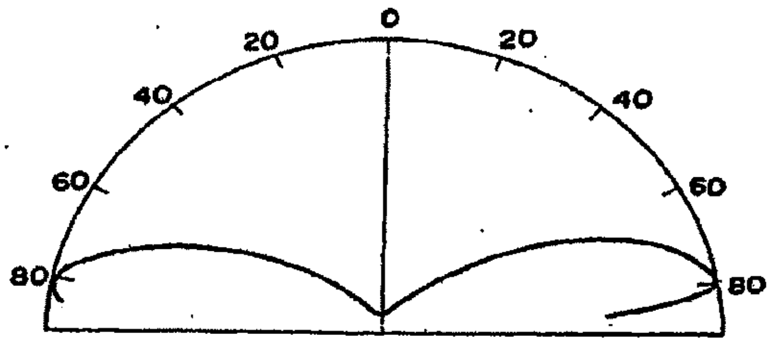


FIG. 8

(d)

Sample-4 Haze 28.8 %

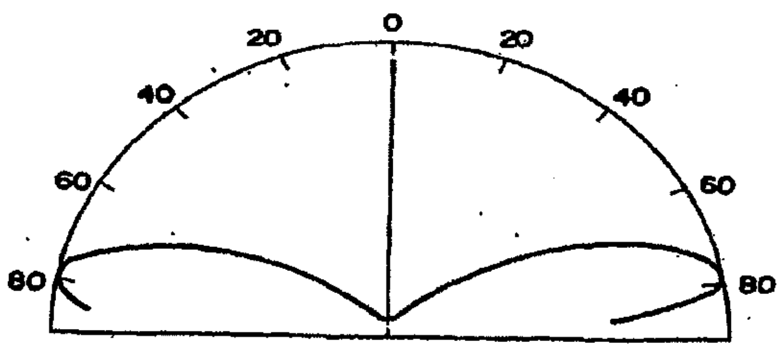
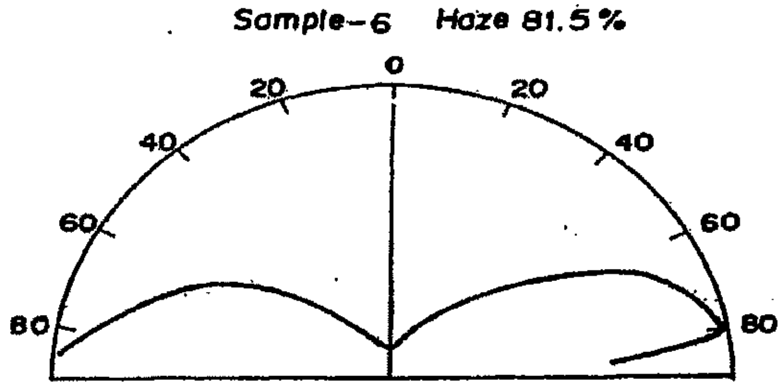


FIG. 8

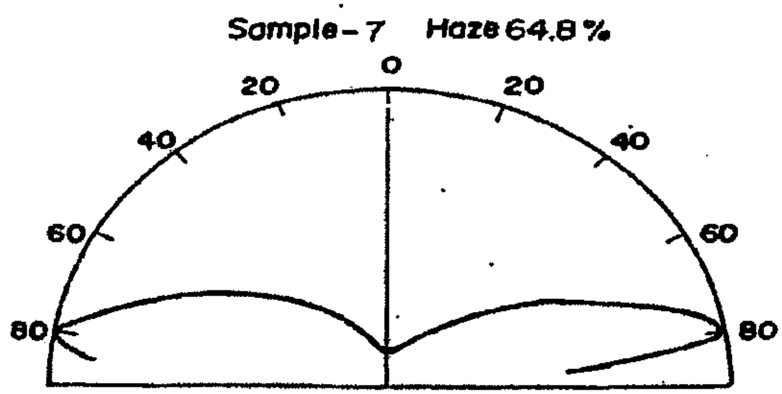
(e)



Sample-6 Haze 81.5 %
0
20
20
40
40
60
60
80
80

FIG. 8

(f)



Sample-7 Haze 64.8 %
0
20
20
40
40
60
60
80
80

FIG. 9

(a)

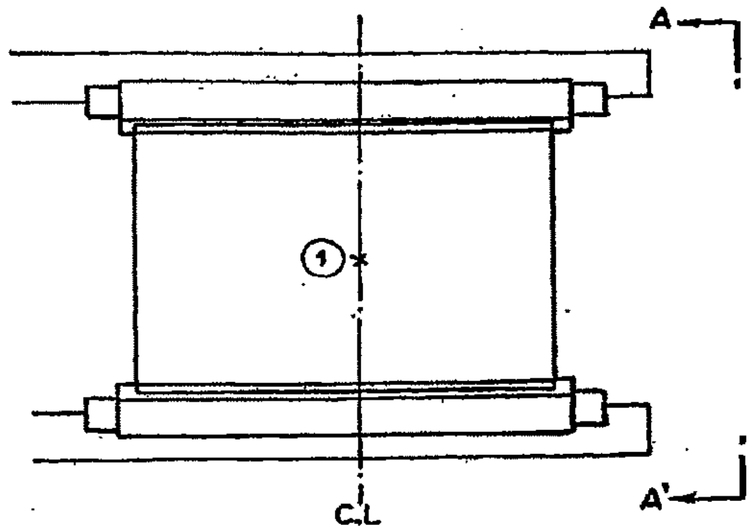


FIG. 9

(b)

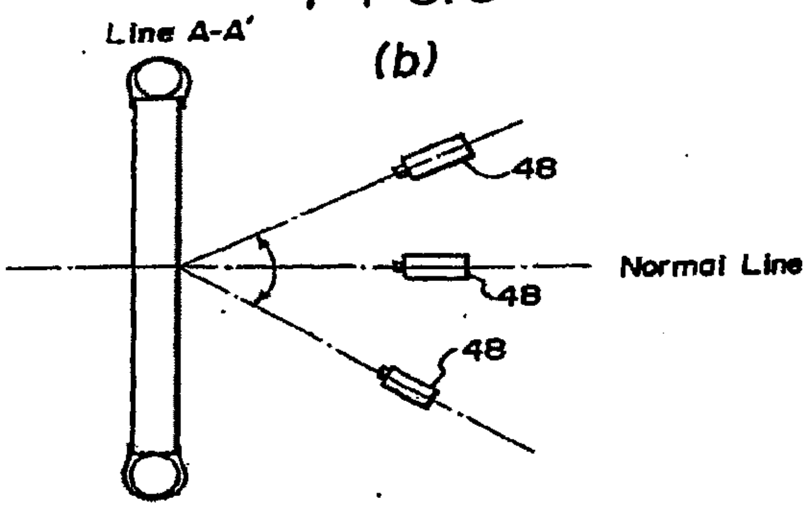


FIG. 10

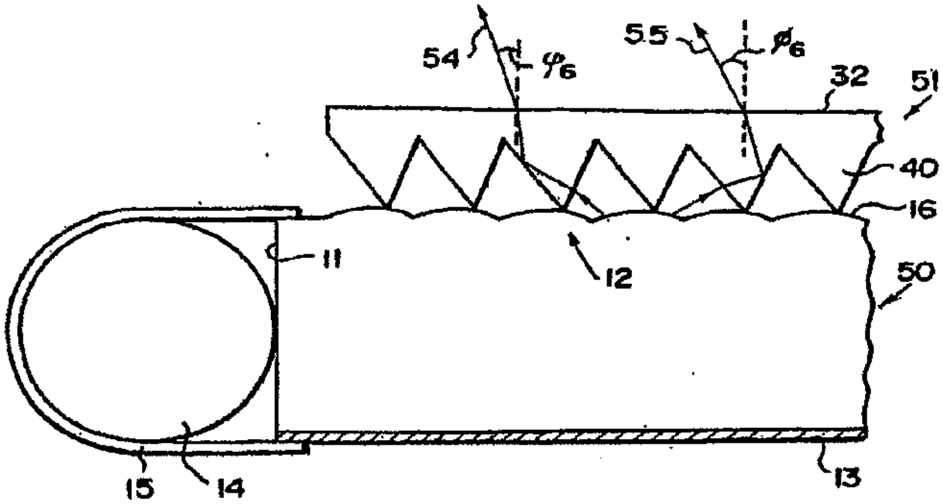


FIG. 11

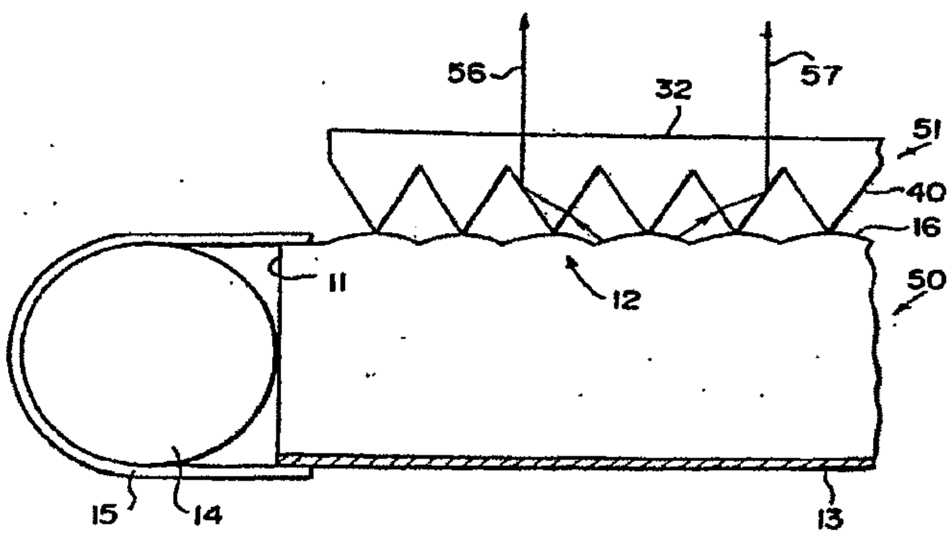


FIG.12

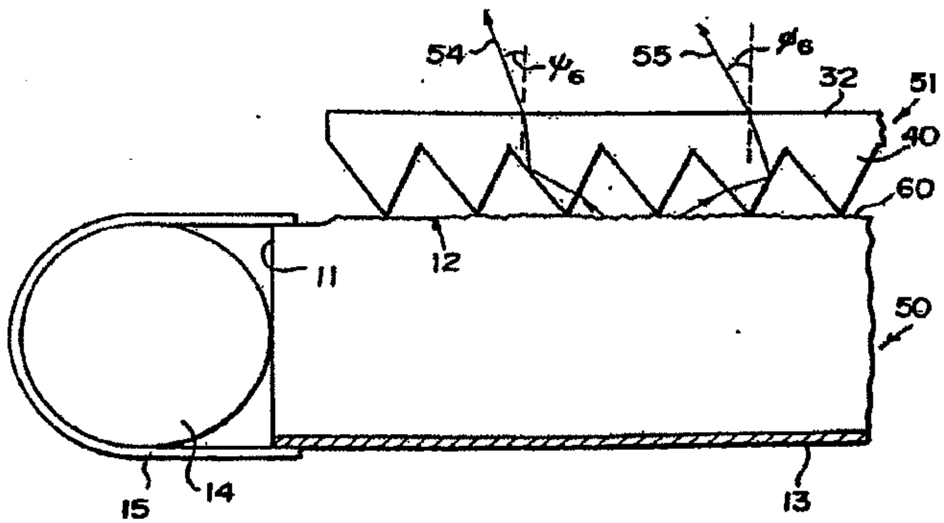

54
ψ_6
55
ϕ_6
32
51
40
60
11
12
50
15
14
13

FIG.13

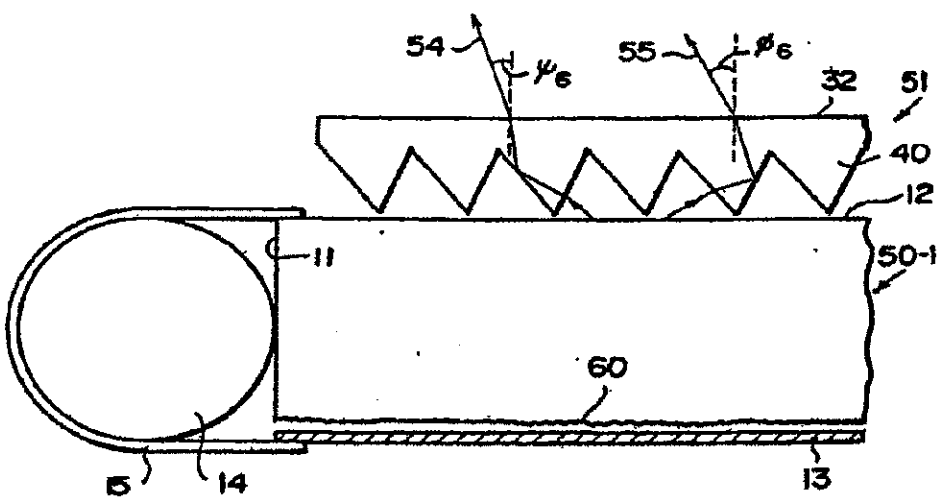
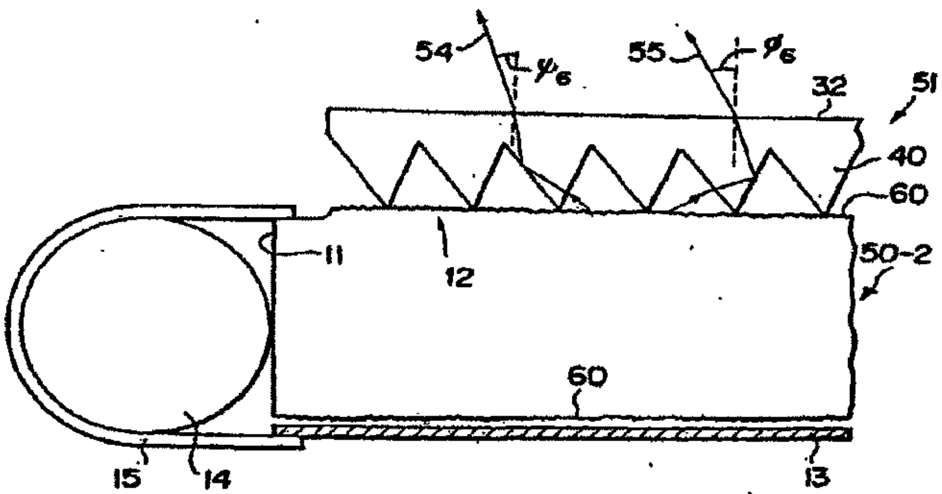
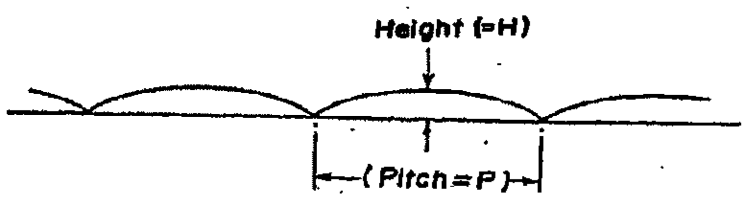

54
ψ_6
55
ϕ_6
32
51
40
12
11
50-1
60
15
14
13

FIG. 14



54
φ_6
55
φ_6
32
51
40
60
11
12
50-2
60
15
14
13

FIG. 15



Height (=H)
(Pitch=P)

FIG. 16 (a)

Central Point ①

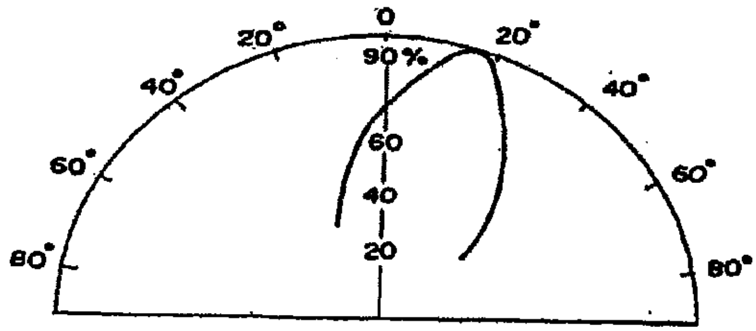


FIG. 16 (b)

10mm Point ② from Lamp

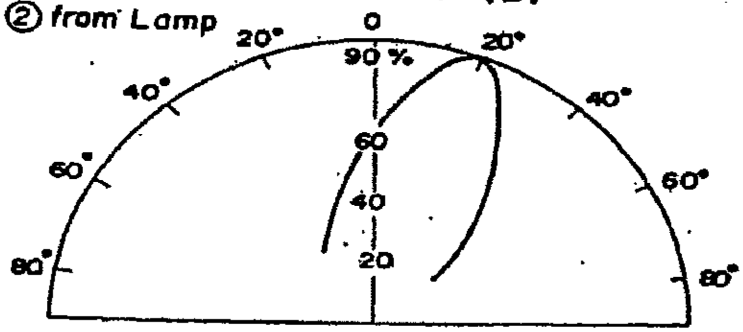


FIG. 16 (c)

10mm Point ③ from Lamp

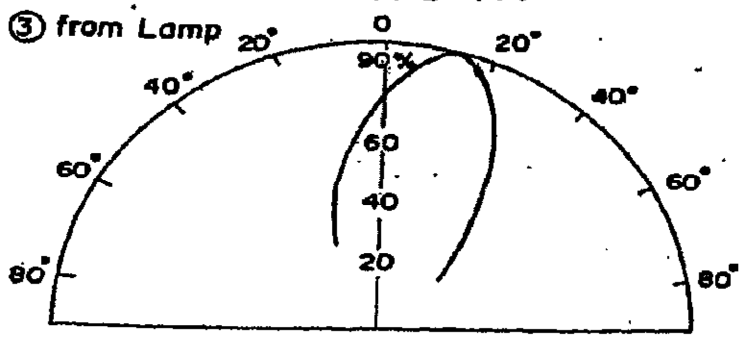


FIG. 17 (a)

Central Point ①

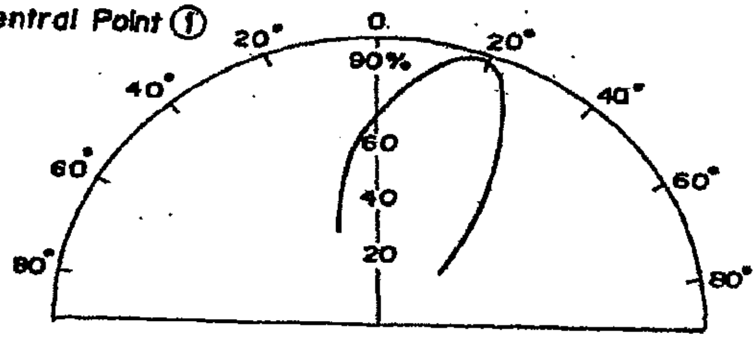


FIG. 17 (b)

10mm Point ② from Lamp

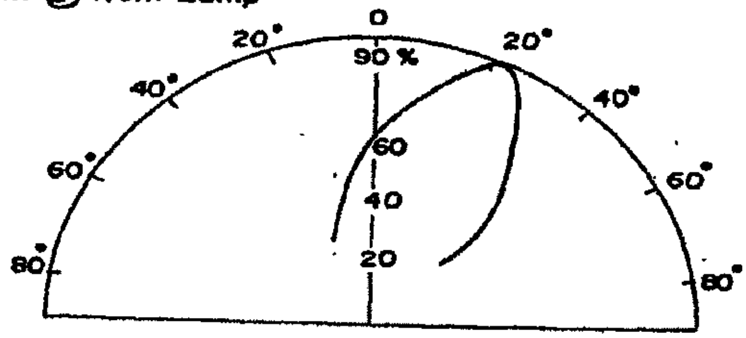


FIG. 17 (c)

10mm Point ③ from Lamp

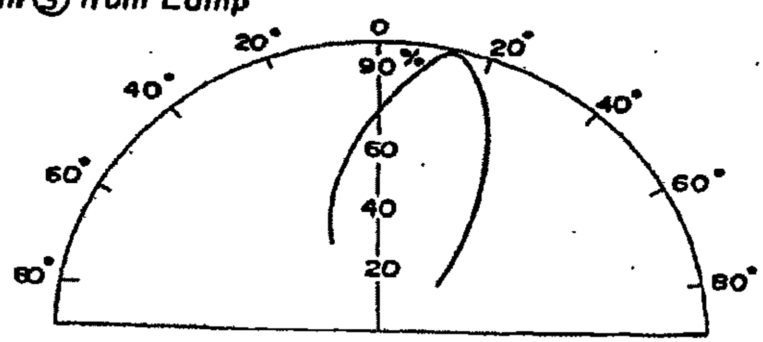


FIG. 18 (a)

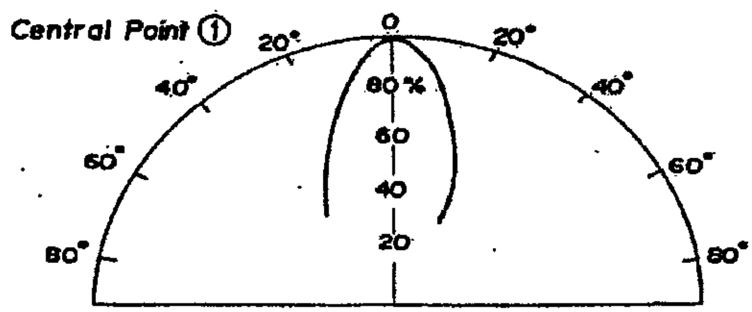


FIG. 18 (b)

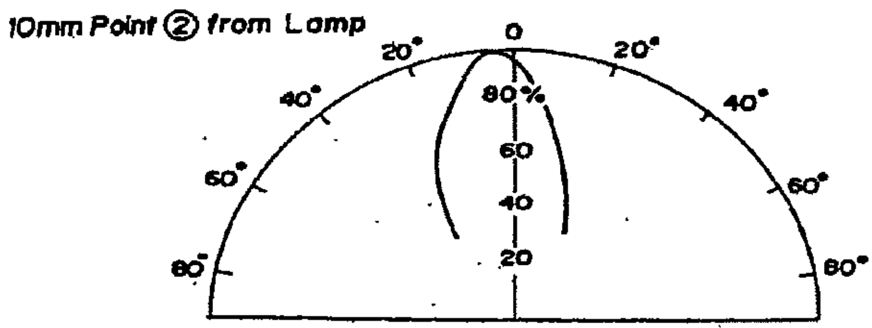


FIG. 18 (c)

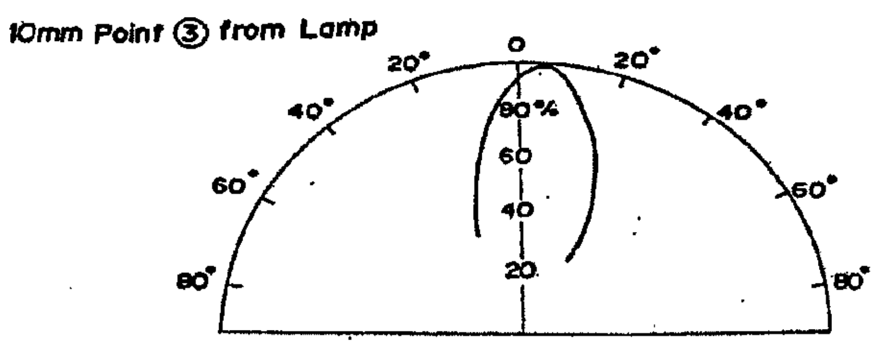


FIG. 19 (a)

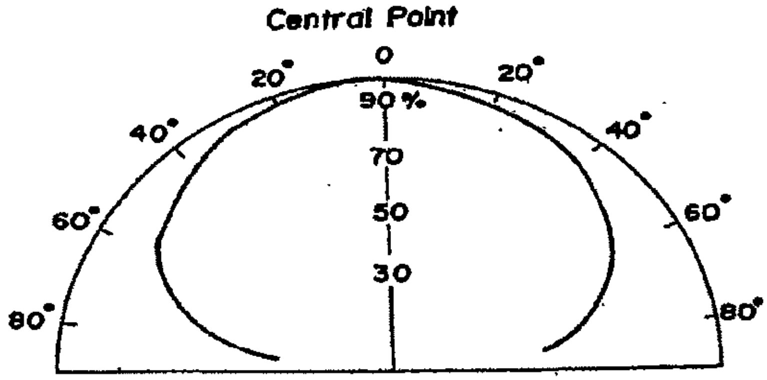


FIG. 19 (b)

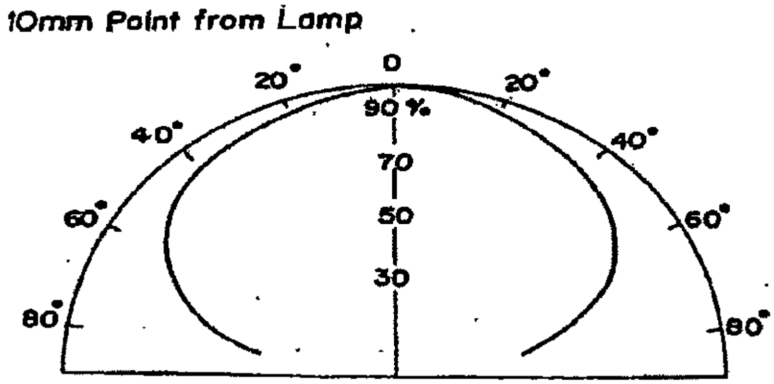


FIG. 20

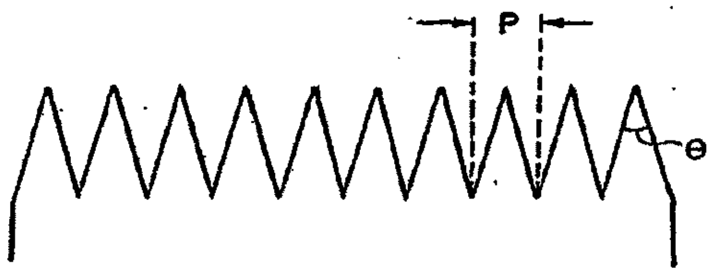


FIG. 21

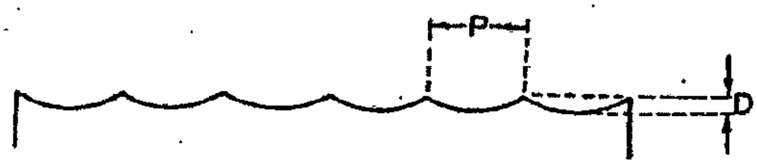


FIG. 22

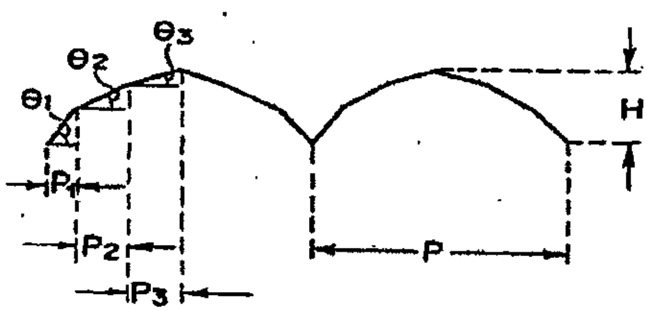


FIG. 23 (a)

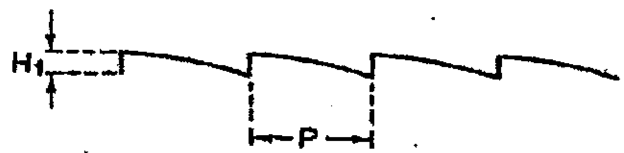


FIG. 23 (b)

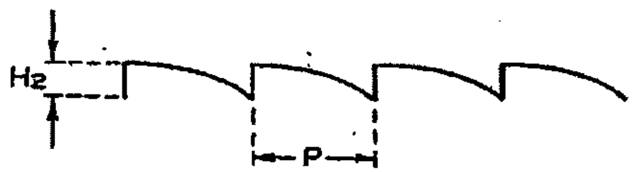


FIG. 24

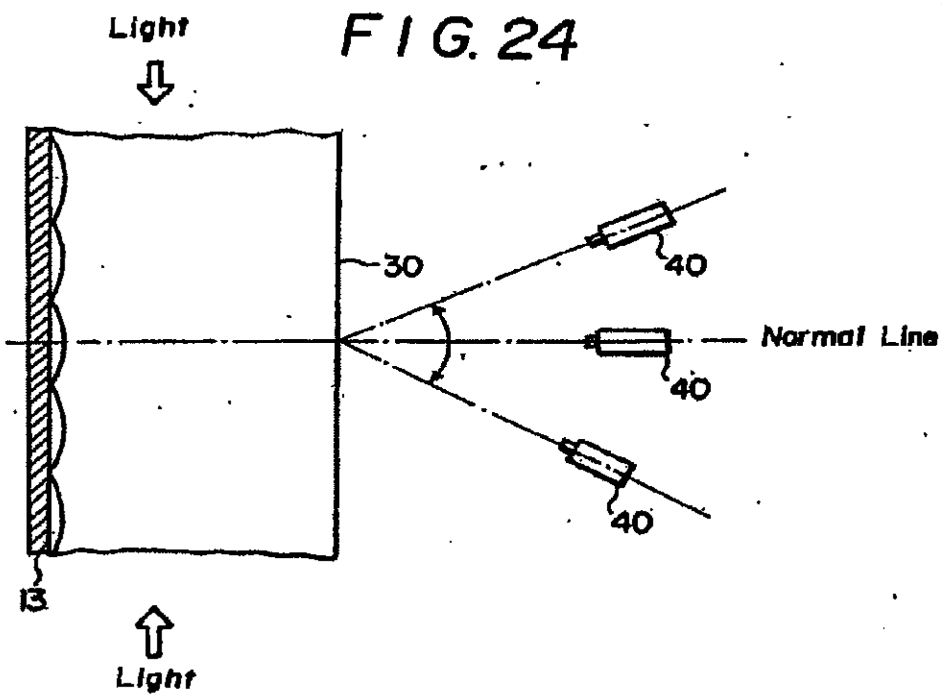


FIG. 25 (a)

Convex Cylindrical Lenticular Lens

Front Type

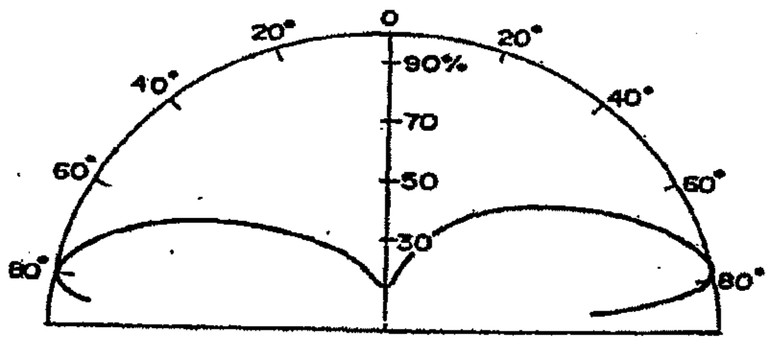


FIG. 25 (b)

Reverse Type

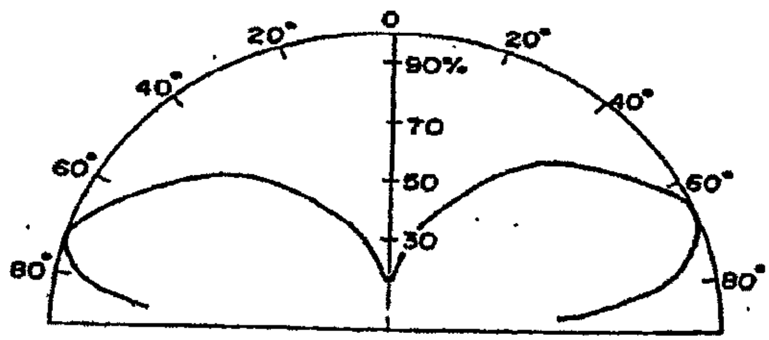


FIG. 26 (a)

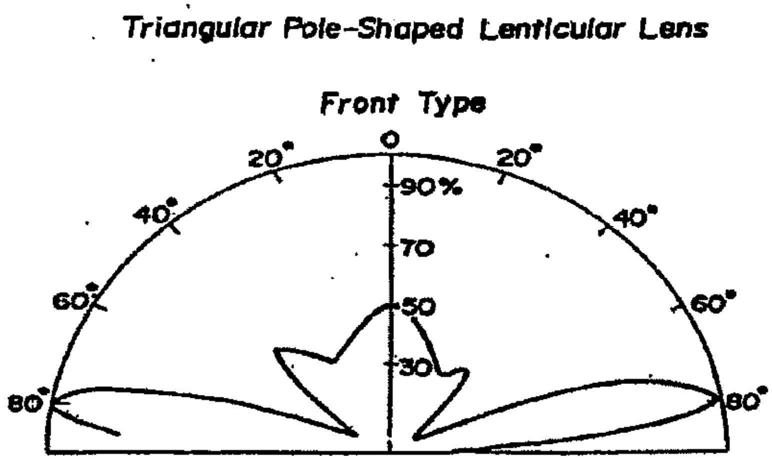


FIG. 26 (b)

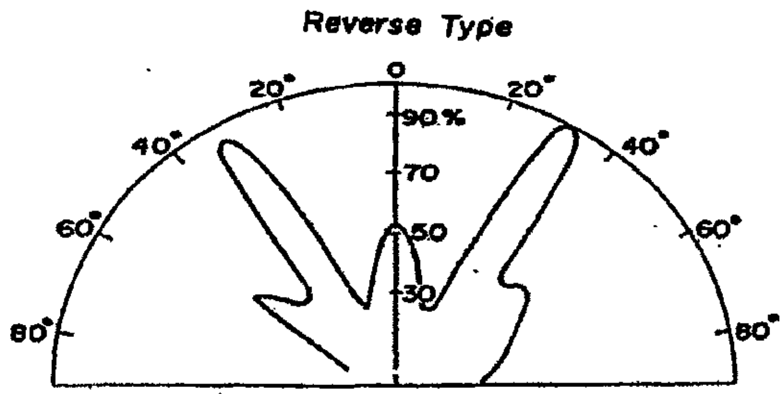


FIG. 27(a)

Concave Cylindrical Lenticular Lens

Front Type

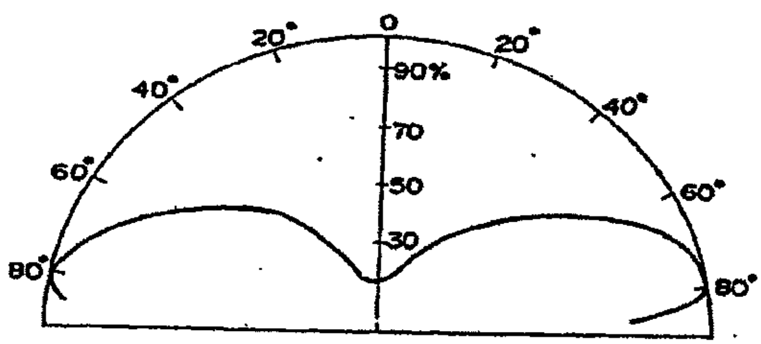


FIG. 27(b)

Reverse Type

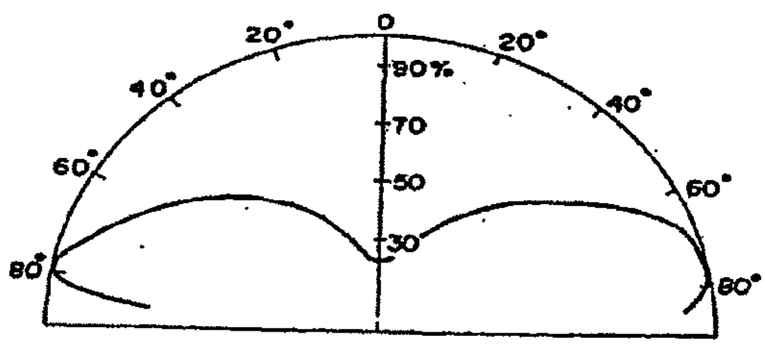


FIG. 28 (a)

Polygonal Pole-Shaped Lenticular Lens

Front Type

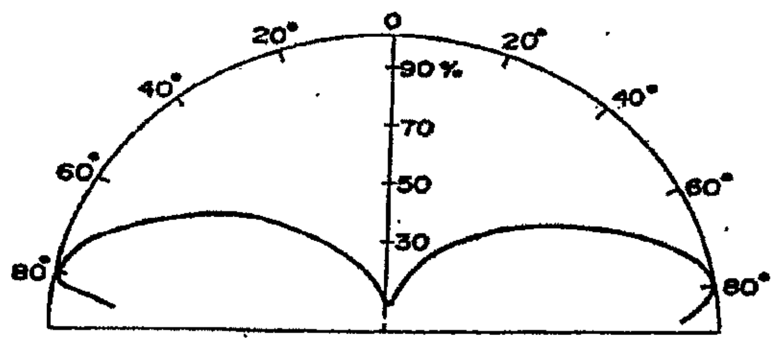


FIG. 28 (b)

Reverse Type

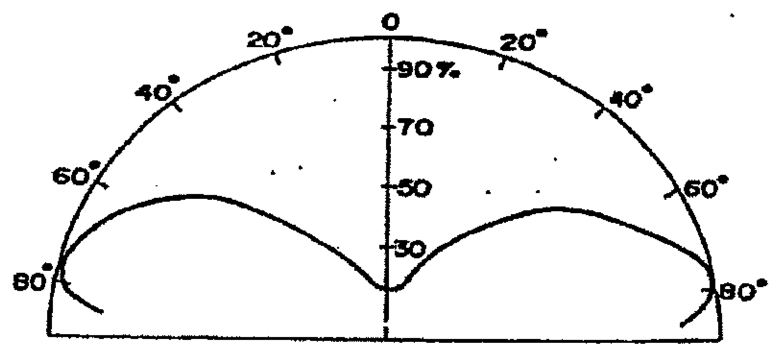


FIG. 29 (a)

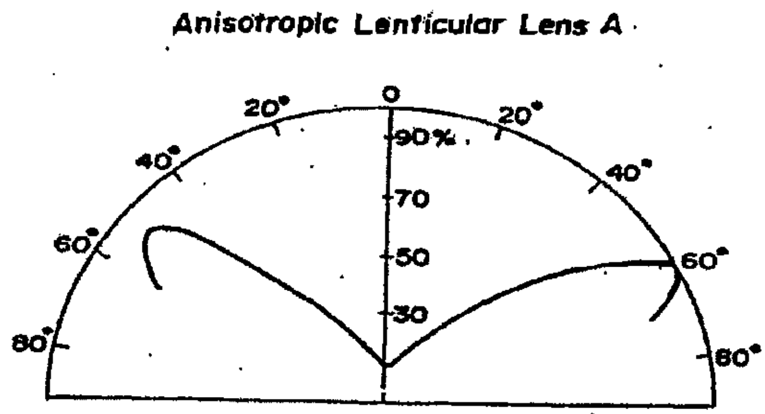


FIG. 29 (b)

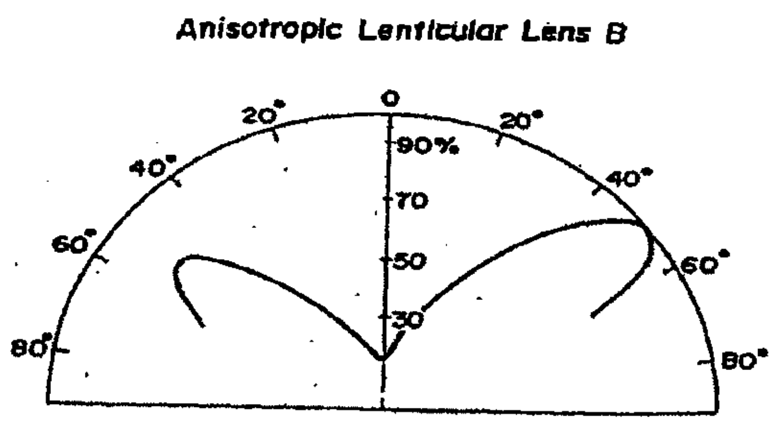


FIG. 30

(a)

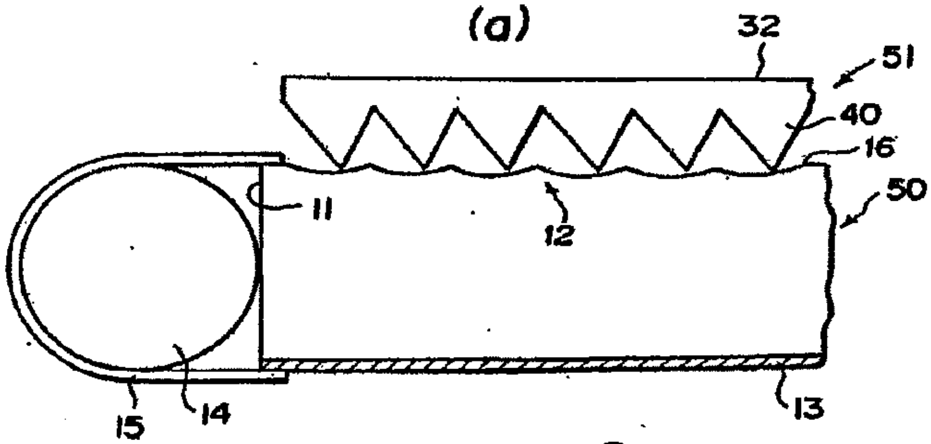


FIG. 30

(b)

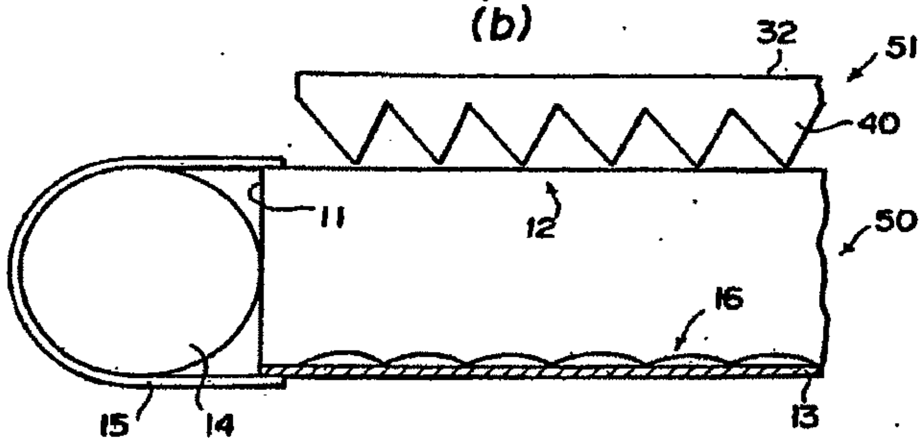


FIG. 31 (a)

Light Distribution
1st Element:
Convex Cylindrical
Lenticular Lens

Front Type

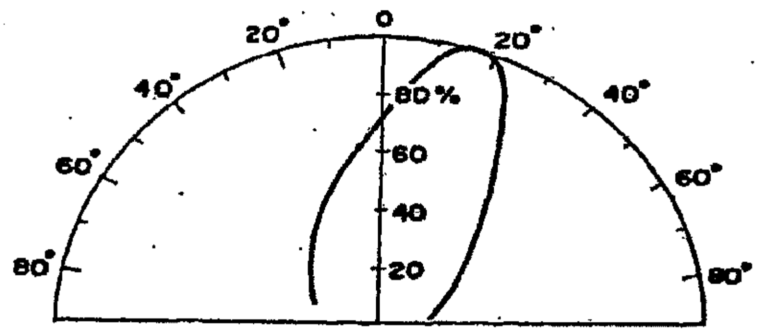


FIG. 31 (b)

Reverse Type

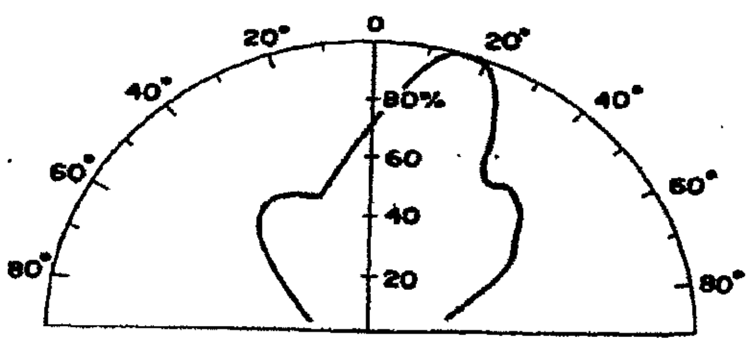


FIG. 32 (a)

Light Distribution
1st Element:
Triangular-Pole Shaped
Lenticular Lens

Front Type

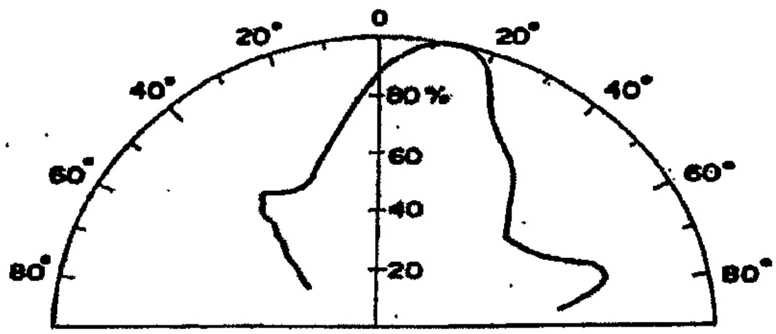
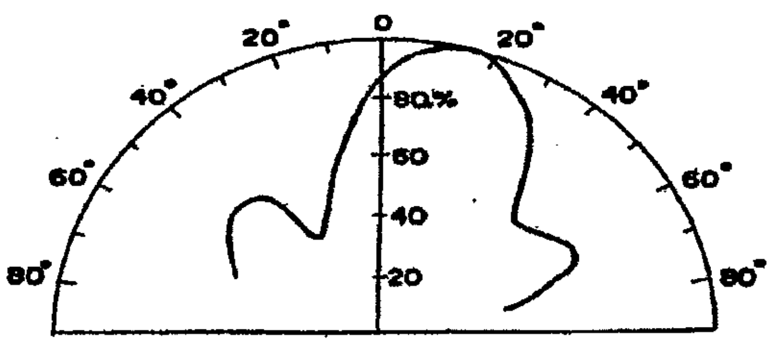


FIG. 32 (b)

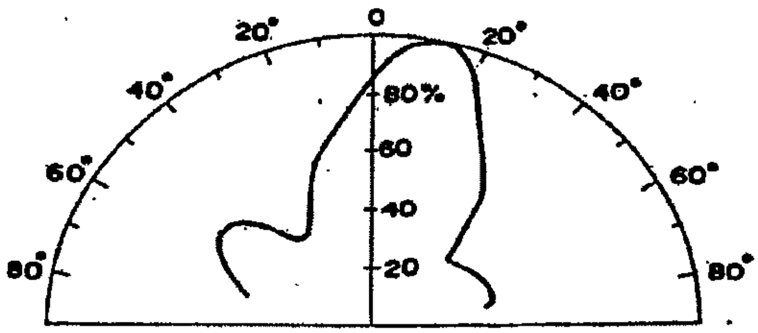
Reverse Type



F I G. 33 (a)

Light Distribution
1st Element:
Concave Cylindrical
Lenticular Lens

Front Type



F I G. 33 (b)

Reverse Type

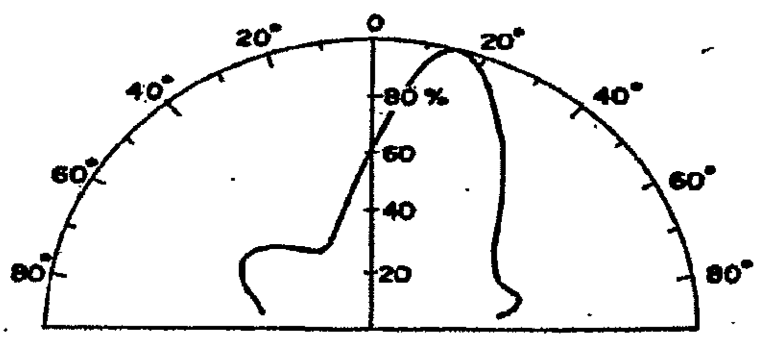


FIG. 34 (a)

Light Distribution
1st Element:
Polygonal-Pole Shaped
Lenticular Lens

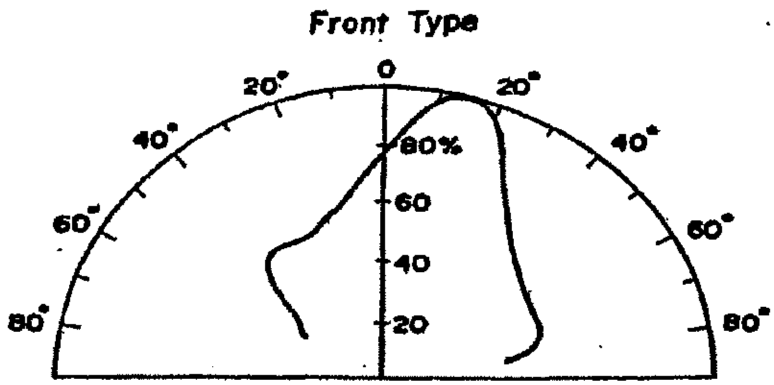


FIG. 34 (b)

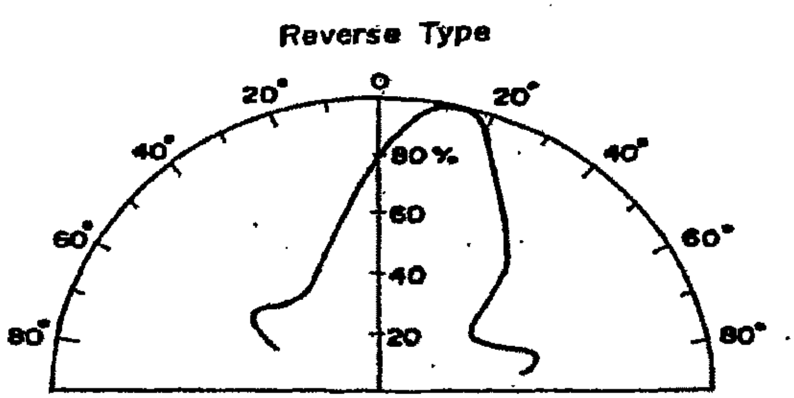


FIG. 35 (a)

Light Distribution
1st Element:
Anisotropic
Lenticular Lens A

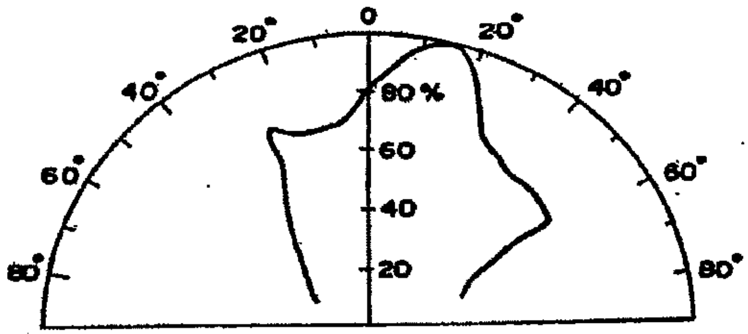


FIG. 35 (b)

Light Distribution
1st Element:
Anisotropic
Lenticular Lens B

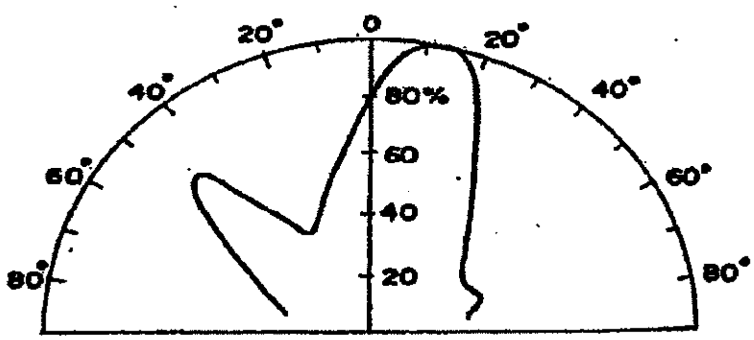


FIG. 36

(a)

Sample-1 Haze 70.8 % Maximum Luminance Value 1660 cd/m²

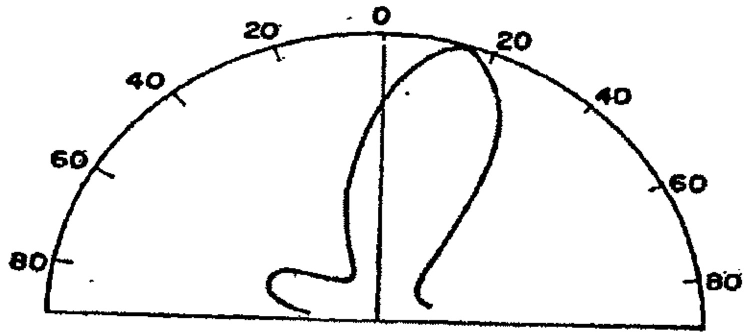


FIG. 36

(b)

Sample-2 Haze 64.8 % Maximum Luminance Value 1450 cd/m²

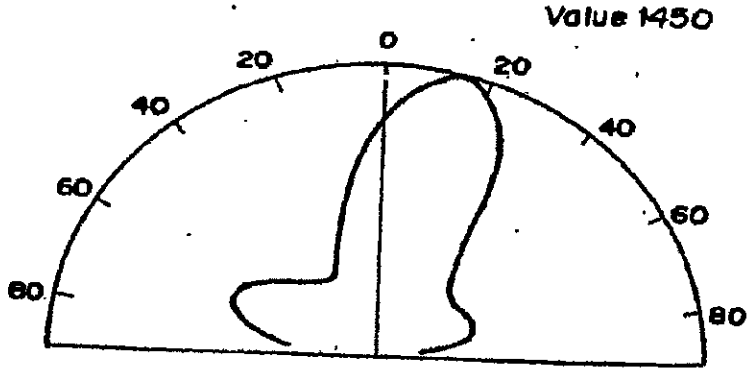


FIG. 36

(c)

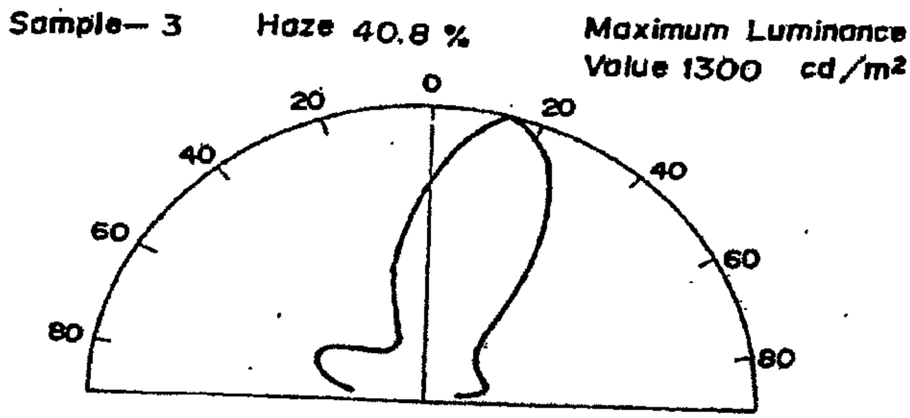


FIG. 36

(d)

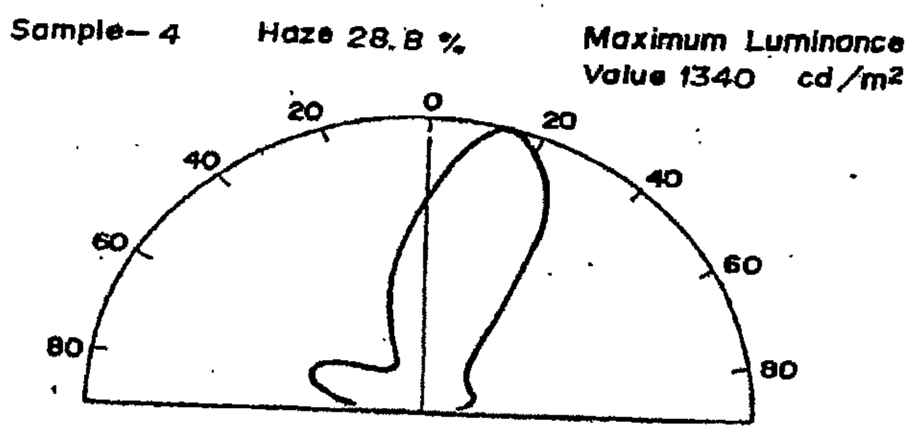


FIG. 36

(e)

Sample—6 Haze 81.5% Maximum Luminance Value 1250 cd/m²

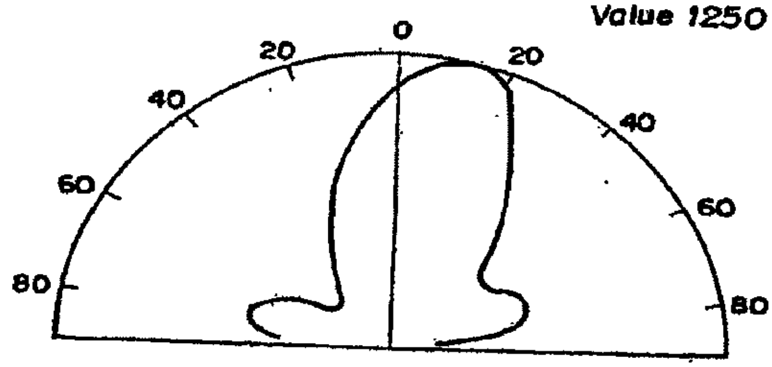


FIG. 36

(f)

Sample—7 Haze 64.8% Maximum Luminance Value 1270 cd/m²

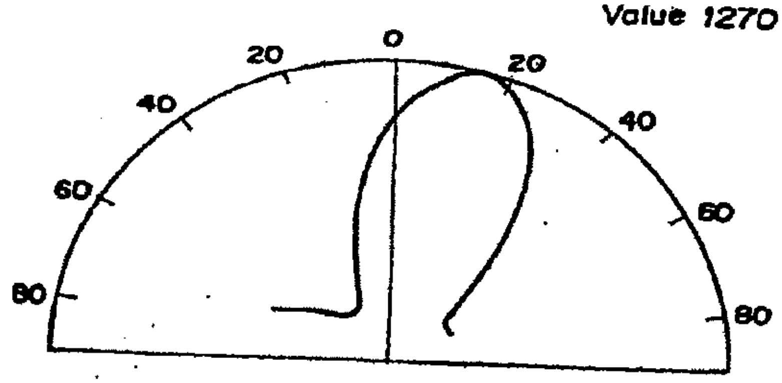


FIG. 37

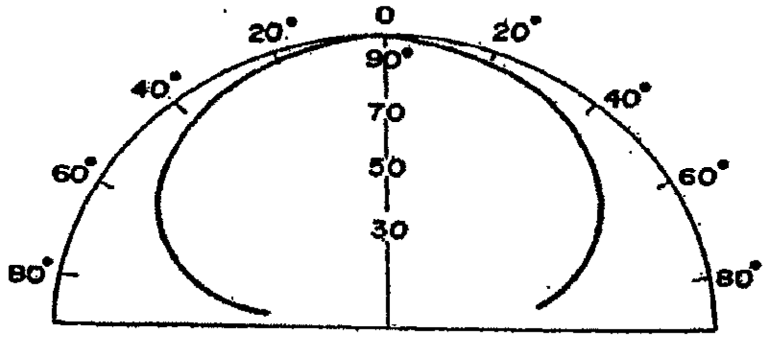
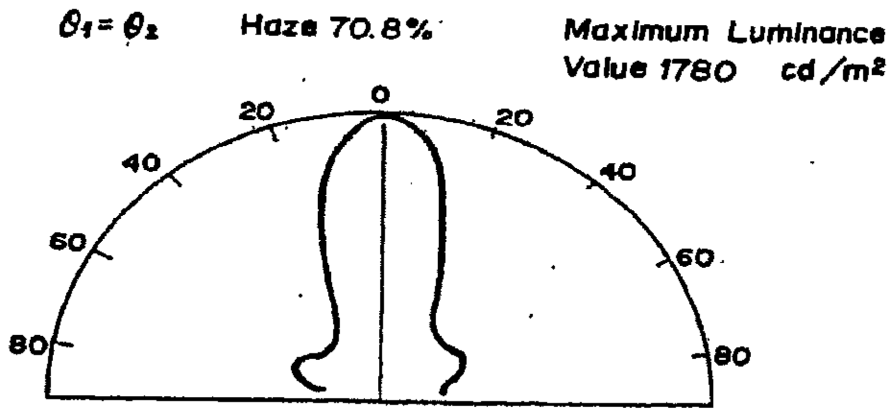

0
20°
20°
90°
40°
40°
70
60°
50
60°
30
80°
80°

FIG. 38


θ1 = θ2
Haze 70.8%
Maximum Luminance
Value 1780 cd/m²
0
20
20
40
40
60
60
80
80

PLANE LIGHT SOURCE UNIT

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to a plane light source unit, and more particularly to a plane light source unit which is applied advantageously as a backlighting means for a liquid crystal display device or the like.

2. Description of the Prior Art

Conventionally, a backlighting means for a liquid crystal display device or the like generally has such a construction that a lamp is located at a focus of a reflector having a parabolic section while a milk-white diffusing plate is located above the lamp. Various inventions have been made to optimize the configuration of a reflector, to adjust the diffusion coefficient of a diffusing plate, and so on.

Special constructions have also been provided which employ such a combination of a linear lamp and a light guide, one side end of which is adjacent to the lamp, and the configuration of the light guide is simulated by approximation to a point source and worked into a curved surface so as to emit the light in a particular direction, or the thickness of the light guide is varied along the direction of light, or else a lenticular is used wherein the prism angle is varied in accordance with the distance from the lamp, or otherwise such configurations as described above are combined suitably. With approximation to a point source, a light path can be simulated in almost every case, and it is possible to change the configuration of a light guide in accordance with the distance in the light direction depending upon such simulation. Such proposals have been made in a large number of patents and utility model registrations. Such plane light sources are disclosed, for example, in U.S. Pat. Nos. 4,126,383, 4,043,636, 4,059,916, 4,373,282, 4,285,889, 4,252,416, 3,546,438, 4,642,736 and 4,648,690 and Japanese Patent Laid-Open No. 62-278505.

While almost all of plane light sources are designed to emit light as uniformly as possible in all directions, it may be sometimes desired to concentrate emitted light in a particular direction depending upon application of a plane light source.

For example, in the case of application to a liquid crystal color TV set for personal use having a comparatively small viewing angle, it is required to emit the light only in a particular direction and make the amount of emitted light as uniform as possible over an entire emitting surface. FIG. 1 shows general construction of a liquid crystal color TV set. Referring to FIG. 1, reference numeral 1 denotes a liquid crystal display, 2 a body of the liquid crystal color TV set, 3 a normal line to the liquid crystal display 1, and 4 an eye of an observer. With the arrangement of the type mentioned, the liquid crystal display 1 is tilted upwardly at an angle of about 45 degrees with respect to the body 2 and is normally observed by an observer in a direction at an angle of about 15 degrees with respect to the normal line 3. Accordingly, a backlighting means which presents a higher luminance within a particular angular range indicated by X than at any other angular position would be advantageous in that the amount of emitted light can be concentrated to the particular angular range. In particular, the luminance of such a plane light source will exhibit a maximum value in a desired direction, which may be several times greater than a luminance value of

an alternative plane light source of the type which emits light uniformly in all directions. Accordingly, if the backlighting means is used in a display device which has a narrow viewing angle in a particular direction, the display device can present a high luminance with a small power consumption.

However, a point source is not used as the light source for a backlighting means of the liquid crystal color TV set shown in FIG. 1 or the like except very rare special cases where the display has a small area. A light source actually used is generally such a volume light source as a fluorescent lamp which cannot be regarded as a point source and is very low in coincidence of approximation to a point source. Accordingly, while such plane light sources as have been proposed in the prior art have accurate and complicated configurations and require a high production cost, it is difficult for them to achieve such desired characteristics as described above.

Besides, light emitted by such a volume light source as a fluorescent lamp is diffused light and non-directive. In a strict sense, it is very difficult to assure a desired directivity using a diffused light emitting source.

Further, in order to obtain a plane light source of small size, it is preferable to make its greatest thickness substantially equal to the diameter of a light source lamp. However, a plane light source device of the type wherein a reflector having a parabolic section is disposed below a lamp as described hereinabove has a thickness substantially equal to twice to four times the diameter of the lamp. Accordingly, the light source device just mentioned cannot meet the requirement of small size.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a plane light source unit which has a reduced thickness substantially equal to the diameter of a lamp so that it is suitable for backlighting for a display device such as a liquid crystal color TV set which is small in size with a small viewing angle.

It is another object of the present invention to provide a plane light source unit which can readily produce light concentrated in a direction to be observed by a user without increasing power consumption.

In order to attain the objects, according to the present invention, there is provided a plane light source unit which comprises a first element having a light incident face at least at one side end thereof and a first light emitting surface extending perpendicularly to the light incident face, the first element further having a reflecting layer provided on a surface thereof opposite to the first light emitting surface, and a second element having a light incident surface which receives the light emitted by the first element and a second light emitting surface through which light is emitted in a predetermined direction, the first light emitting surface and/or the opposite surface of the first element having a directive function to cause incident light through the light incident face to emit through the first light emitting surface in a direction oblique to the direction of the light, the second element having a large number of prism units formed on the light incident surface thereof.

The above and other objects, features and advantages of the present invention will become apparent from the following description and the appended claims, taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a diagrammatic representation illustrating relative angles of a liquid crystal color TV set in an observed condition;

FIGS. 2(a) and 2(b) are schematic sectional views of a conventional plane light source device;

FIGS. 3(a) and 3(b) are a schematic perspective view and a schematic sectional view, respectively, showing a first element of a plane light source unit of the present invention together with lamp units;

FIGS. 4(a) and 4(b) are diagrams showing angular distributions of light emitted by a first element of an example 1-1 of the present invention;

FIG. 5(a) is a schematic front elevational view illustrating a method of measuring angular distributions of light emitted by a plane light source unit of the present invention, and FIG. 5(b) is a diagrammatic representation as viewed in a direction indicated by arrow marks A—A' of FIG. 5(a);

FIGS. 6(a) and 6(b) are diagrammatic representations illustrating paths of rays of light passing through a prism;

FIGS. 7(a) and 7(b) are a schematic perspective view and a schematic sectional view, respectively, showing a first element of a plane light source unit of the present invention together with lamp units;

FIGS. 8(a) to 8(f) are diagrams showing angular distributions of light from different first elements of the present invention;

FIGS. 9(a) and 9(b) are diagrammatic representations illustrating a method of measuring an angular distribution of light;

FIGS. 10 and 11 are schematic sectional views showing different plane light source units according to the present invention together with lamp;

FIG. 12 is a schematic sectional view but showing a further different plane light source unit according to the present invention;

FIGS. 13 and 14 are schematic sectional views but showing still further different plane light source unit according to the present invention;

FIG. 15 is a schematic view illustrating an example of lens unit of a first element;

FIGS. 16(a), 16(b) and 16(c) are diagrams showing angular distributions of light in the case of the example 1-1;

FIGS. 17(a), 17(b) and 17(c) are diagrams showing angular distributions of light in the case of another example 1-2;

FIGS. 18(a), 18(b) and 18(c) are diagrams showing angular distributions of light in the case of a further example 1-3;

FIGS. 19(a) and 19(b) are diagrams showing angular distributions of light in the case of a plane light source device of a comparative example;

FIG. 20 is a schematic sectional view showing a first element wherein lens units are triangular pole-shaped lenticular lenses;

FIG. 21 is a schematic sectional view showing another first element wherein lens units are concave cylindrical lenticular lenses;

FIG. 22 is a schematic sectional view showing a further first element wherein lens units are convex polygonal pole-shaped lenticular lenses;

FIGS. 23(a) and 23(b) are schematic sectional views showing still further first elements wherein lens units are different anisotropic lenticular lenses;

FIG. 24 is a diagrammatic sectional view illustrating a manner of measuring angular distributions of light from a first element of reverse type;

FIGS. 25(a) and 25(b) are diagrams showing angular distributions of light emitted by first elements in the case of the front and reverse types, respectively, wherein convex cylindrical lenticular lenses are employed;

FIGS. 26(a) and 26(b) are diagrams showing angular distributions of light emitted by first elements in the case of the front and reverse types, respectively, wherein triangular pole-shaped lenticular lenses are employed;

FIGS. 27(a) and 27(b) are diagrams showing angular distributions of light emitted by first elements in the case of the front and reverse types, respectively, wherein concave cylindrical lenticular lenses are employed;

FIGS. 28(a) and 28(b) are diagrams showing angular distributions of light emitted by first elements in the case of the front and reverse types, respectively, wherein polygonal pole-shaped lenticular lenses are employed;

FIGS. 29(a) and 29(b) are diagrams showing angular distributions of light emitted by first elements in the case of the front and reverse types, respectively, wherein different anisotropic lenticular lenses are employed;

FIGS. 30(a) and 30(b) are schematic sectional views showing different plane light source units of the front and reverse types which employ different concave cylindrical lenticular lenses, respectively, together with lamp;

FIGS. 31(a) and 31(b) are diagrams showing angular distributions of light emitted by plane light source units of the front and reverse types which employ convex cylindrical lenticular lenses, respectively;

FIGS. 32(a) and 32(b) are diagrams showing angular distributions of light emitted by plane light source units of the front and reverse types which employ triangular pole-shaped lenticular lenses, respectively;

FIGS. 33(a) and 33(b) are diagrams showing angular distributions of light emitted by plane light source units of the front and reverse types which employ concave cylindrical lenticular lenses, respectively;

FIGS. 34(a) and 34(b) are diagrams showing angular distributions of light emitted by plane light source units of the front and reverse types which employ polygonal pole-shaped lenticular lenses, respectively;

FIGS. 35(a) and 35(b) are diagrams showing angular distributions of light emitted by plane light source units of the front and reverse types which employ different anisotropic lenticular lenses;

FIGS. 36(a) to 36(f) are diagrams showing angular distributions of light emitted by different surface light source units of the present invention;

FIG. 37 is a diagram showing an angular distribution of light emitted by a surface light source device of comparative example; and

FIG. 38 is a diagram showing an angular distribution of light emitted by a plane light source unit of the $\theta_1=\theta_2$ type according to the present invention.

DETAILED DESCRIPTION OF THE INVENTION

Prior to description of the preferred embodiments of the present invention, a basic concept of a plane light

source unit according to the present invention will be described.

The refractive index of a light guide with respect to air is generally n=1.5 to 1.6 or so, and in the case of such a configuration as shown in FIG. 2(a) wherein a light incident face 11 and a light emitting surface 12 of a light guide 10 extend in perpendicular directions to each other (i.e., edge lighting configuration), the critical angle is about 45 degrees at which no light is emitted through the surface 12 in principle. It is to be noted that, in FIG. 2(a), reference numeral 14 represents a light source such as a fluorescent lamp, 15 a reflector for the fluorescent lamp 15, and 13 a reflecting layer formed on the opposite side of the light guide 10 to the surface 12.

Generally, either the surface 12 is formed into a light diffusing surface 12a or the reflecting layer 13 is formed into a light diffusing reflecting layer 13a as shown in FIG. 2(b). However, for the present object of directivity of emitted light, such means cannot be employed by itself because light emitted by the light guide 10 becomes diffused light.

Thus, construction of a device is considered wherein a number of linear convex lenses 16 of a same profile are formed, on an emitting surface such that they extend in the same direction while a reflecting layer 13 is formed on a surface opposite to the emitting surface, and linear light sources 14 such as fluorescent lamps are arranged in parallel to the linear convex lenses 16 at opposite ends of the first element. FIG. 3(a) is a schematic perspective view showing such a construction described just above, and FIG. 3(b) is a schematic sectional view taken along line A—A' of FIG. 3(a).

With such a geometrical positional relationship, the direction of emitted light falls within an angular range of 40 to 60 degrees with respect to the normal line to the imaginary plane of the light emitting surface having convex lenses 16, and little light is emitted in the normal line direction (refer to FIG. 3(b)).

FIGS. 4(a) and 4(b) are diagrams illustrating angular distributions of light illustrated in FIG. 3(b) within a plane perpendicular to the direction of the convex lenses 16. In particular, the diagrams show rates of luminance at various angles where the maximum luminance value is represented by 100 percent.

FIGS. 5(a) and 5(b) are diagrammatic representations illustrating a luminance measuring method, and FIG. 5(a) is a front elevational view of a plane light source unit together with lamps showing positions at which luminance is measured, and FIG. 5(b) is a diagrammatic representation as viewed in a direction indicated by arrow marks A—A' of FIG. 5(a). In FIG. 5(b), reference numeral represents a luminance meter.

FIG. 4(a) shows an angular distribution of light at the central point (1) shown in FIG. 5(a) while FIG. 4(b) shows another angular distribution of light at another position (2) spaced by a distance of 10 mm from the lamp. It can be seen also from the graphs that there is little light emitted in the normal line direction.

Thus, a plane light source unit of the present invention is constructed in its principle such that a number of lenses such as the lenses 16 are employed wherein light emitted through the lenses is concentrated in a particular direction so that the distribution of light falls within a narrow range and besides the amount of emitted light is large, and the light emitted toward the opposite sides of the normal line such as the lights 20, 21 illustrated in FIG. 3(b) are refracted by a set of prisms serving as a second element so as to concentrate the light in a desired direction.

FIGS. 6(a) and 6(b) are diagrammatic representations showing one of such prisms of the second element as described just above. In FIGS. 6(a) and 6(b), reference numerals 20 and 21 represent emergent rays of light in the rightward and leftward directions, respectively, from the lens set 16 of the first element, θ_1 and θ_2 represent angles made by the normal lines and surfaces 31 and 30 of the prism, respectively, and reference numeral 32 represents an emergent surface (a second light emitting surface) of the prism. Further, reference symbols Ψ_1 to Ψ_6 and Ψ_1 to ϕ_6 denote angles of rays with respect to the individual surfaces of the prism or reference lines. The angles are taken as shown in FIGS. 6(a) and 6(b).

Referring to FIG. 6(b), if a ray of light enters the prism from the right-hand side like a ray 21, it enters through the prism surface 30, then is totally reflected by the prism surface 31, and then emerges from the prism through the emergent surface 32 at a predetermined angle Ψ_6. To the contrary, referring to FIG. 6(a), if a ray of light enters the prism from the left-hand side like a ray 20, it enters through the prism surface 31 and then is totally reflected by the prism surface 30 whereafter it emerges at the predetermined angle ϕ_6 from the prism through the emergent surface 32. The predetermined angles Ψ_6 and ϕ_6 can be adjusted by the configuration of the lens units of the first element and the emergent angle from the lens set, the angles θ_1 and θ_2 and the refraction index n of the lens set.

It is to be noted that the configuration of the lenses 16 of the first element is not particularly limited and may be any one if emergent rays of light are concentrated in a particular direction so that the distribution of emitted light falls within a narrow range and besides the amount of emitted light is large. Further, while the lights 20, 21 may not always be emitted symmetrical to each other with respect to the normal line depending upon a configuration of the lens set 16 of the first element, in such a case the light can be emitted by the second element in a desired direction by varying the prism angles (θ_1 and θ_2 of FIG. 6) of each prism which is a component unit of a prism set of the second element.

It is to be noted that, as a special example of the present invention, where the first element emits the light at an angle of 60 degrees with respect to the normal line, the prism angles of the second element (θ_1 and θ_2 of FIG. 6) may be set to $\theta_1=\theta_2=30$ degrees in order to direct the light from the first element to the direction of the normal line.

Meanwhile, also as will be hereinafter described with reference to several embodiments of the present invention, the amount of light emitted by the light guide in the normal line direction I is very small (refer to FIG. 7(b)). Thus, the inventors examined a directivity of emitted light with a finely roughened surface formed by roughening a surface of a light guide serving as a first element as uniformly as possible. Such an examination revealed that almost all of light is emitted in directions of 70 to 80 degrees with respect to the normal line to the emitting surface. The present invention has been completed by an idea to combine the above light guide and a second element in order to change the direction of the light to the normal line direction. Here, the term "finely roughened surface" signifies a so-called "mat finished surface" and contains what is so-called "orange peel".

Construction of the first element is shown in a perspective view of FIG. 7(a). Referring to FIG. 7(a), a

light emitting surface of the first element is mat finished uniformly while a reflecting layer 13 is formed on the opposite surface of the first element, and linear light sources 14 such as fluorescent lamps are arranged at opposite ends of the first element. FIG. 7(*b*) is a sectional view taken along line A—A' of FIG. 7(*a*).

FIGS. 8(*a*) to 8(*f*) are diagrams illustrating angular distributions of light shown in FIG. 7(*b*). In particular, FIGS. 8(*a*) to 8(*f*) illustrate rates of luminance at various angles where the maximum luminance value is represented by 100 percent (samples for measurement and measuring methods will be described below).

FIGS. 9(*a*) and 9(*b*) are diagrammatic representations illustrating measuring methods, and FIG. 9(*a*) is a front elevational view showing a measuring point and FIG. 9(*b*) is a view in the direction indicated by arrow marks A—A' of FIG. 9(*a*). In FIG. 9(*b*), reference numeral 48 represents a luminance meter. The results of the measurements are shown in FIGS. 8(*a*) to 8(*f*) from which it can be seen that little light is emitted in a direction normal to the emitting surface but emitted light is concreted in particular directions of 75 to 80 degrees (as also seen in FIG. 7(*b*)). Thus, the present invention is made on a principle that, making use of a light guide (first element) which has a mat finished emitting surface wherein emitted light is concentrated in a particular direction so that the distribution of light falls within a narrow range and the amount of emitted light is large, light 20 and 21 (refer to FIG. 7(*b*)) emitted toward the opposite sides of the normal line i are all refracted by a prism set serving as a second element to concentrate the light in a desired direction.

The prisms of the second element which makes another component for the function described above are similar to that shown in FIGS. 6(*a*) and 6(*b*).

It is to be noted that since the light emitted through the mat finished surface 60 of the first element is symmetrical with respect to the normal line, desired angles (Ψ_6 and ϕ_6) can be obtained by varying the prism angles (θ_1 and θ_2 of FIG. 6) and the refraction index of the second element.

In the following, particular construction of several plane light source units according to the present invention will be described in detail with reference to the drawings.

FIG. 10 is a partial sectional view showing an embodiment of plane light source unit according to the present invention together with a lamp and is a view corresponding to FIG. 3(*b*).

Referring to FIG. 10, reference numeral 14 represents a light source such as a fluorescent lamp, 15 a reflector, 13 a reflecting layer formed on the opposite side to a first light emitting surface 12 of a first element 50, 16 a lens unit like the lens described hereinabove, 40 a prism unit, and a second light emitting surface 32. It is to be noted that the lens units 16 and the prism units 40 have convex linear configurations extending in a direction parallel to the light source (lamp).

The plane light source unit of the present embodiment thus comprises a first element 50 having a light incident face at least at one side end 11 of a light guide and a first light emitting surface which extends in a perpendicular direction to the incident face and on which the lens units 16 are formed, the first element 50 further having a reflecting layer 13 on the opposite surface of the light guide to the first light emitting surface, and a second element 51 having an incident surface on which the prism units 40 into which light from the first element 50 is introduced in predetermined directions are formed and a second light emitting surface 32. Light rays emerging from the individual lens units 16 are caused to emerge from the second element as represented by light rays 54 and 55, and the object of the invention can be attained by setting the lens units and the prism units such that the angles Ψ_6 and ϕ_6 may be substantially equal to each other.

FIG. 11 is a diagrammatic representation showing an embodiment of plane light source unit wherein the lens units of the first element are set such that emergent light rays may emerge at angles of 60 degrees with respect to the normal line and the angles (θ_1 and θ_2 of FIG. 6) of the prism units of the second element 51 are set to $\theta_1/\theta_2=30$ degrees. According to the embodiment, light emitted through the second light emitting surface 32 of the second element can be concentrated in the normal line direction as represented by light rays 56 and 57.

The elements of the plane light source unit of the present invention may be preferably made of such a material as an acrylic resin or a polycarbonate resin which has a higher transmittance to visible light to attain the object of small size and light weight, but the material of the elements need not be limited to such a specific material.

Further, while a small size fluorescent lamp is used as the light source 14, a linear light source having continuous configuration (for example, a filament lamp may be employed instead.

Subsequently, an example of determination of prism angles where the primary emergent rays from the first element emerge symmetrically to each other with respect to the normal line will be described. Also where the primary emergent rays do not emerge symmetrically to each other with respect to the normal line, prism angles can be determined in a similar manner. It is to be noted that a character n represents a refraction index of a material which constitutes the element.

(1) Where a light ray enters from the left-hand side of a prism: (all symbols are based on FIG. 6(*a*))

Where $90° - \psi < \theta_1$: (i)

$\phi_1 = (\theta_1 + \psi) - 90,$
$\sin\phi_2 = \sin(\theta_1 + \psi - 90)/n,$
$\phi_5 = 90 - (2\theta_2 + \theta_1 - \phi_2),$
$\sin\phi_6 = n \times \sin\phi_5,$
$\phi_6 = \sin^{-1}(n \times \sin\phi_5)$

Where $90° - \psi > \theta_1$: (ii)

$\phi_1 = 90 - (\theta_1 + \psi),$
$\sin\phi_2 = \sin(90 - \theta_1 - \psi)/n,$
$\phi_5 = 90 - (2\theta_2 + \theta_1 + \phi_2),$
$\sin\phi_6 = n \times \sin\phi_5$

Where $90° - \psi = \theta_1$: (iii)

$\phi_1 = 0,$
$\phi_5 = 90 - (2\theta_2 + \theta_1),$
$\sin\phi_6 = n \times \sin\phi_5$

(2) Where a light ray enters from the right-hand side of a prism: (all symbols are based on FIG. 6(*b*))

Where $90° - \psi < \theta_2$: (iv)

$\psi_1 = (\theta_2 + \psi) - 90,$
$\sin\psi_2 = \sin(\theta_2 + \psi - 90)/n,$
$\psi_5 = (2\theta_1 + \theta_2 - \psi_2) - 90,$
$\sin\psi_6 = n \times \sin\psi_5,$

Where $90° - \psi > \theta_2$: (v)

$\psi_1 = 90 - (\theta_2 + \psi),$
$\sin\psi_2 = \sin(90 - \theta_2 - \psi)/n,$
$\psi_5 = (2\theta_1 + \theta_2 + \psi_2) - 90,$

-continued

$$\sin\phi_4 = n \times \sin\psi_3$$

$$\text{Where } 90° - \psi = \theta_3; \quad \psi_1 = 0, \quad \psi_3 = (2\theta_2 + \theta_3) - 90, \quad \sin\phi_5 = n \times \sin\psi_3 \qquad \text{(vi)}$$

Meanwhile, where the prisms are made of an acrylic resin material, the refraction index is n=1.49, and if it is assumed that the incident angles to the prism 40 are symmetrical and Ψ=55 degrees with respect to the normal line, the emergent angles of emergent light rays from the prisms calculated in accordance with the expressions given above are concentrated on the one side with respect to the normal line (only examples of calculations are given wherein the difference in emergent angle between two light rays from the left and right sides falls within 2 degrees).

θ_1	θ_2	Light from the Left-Hand Side (ϕ_4)	Light from the Right-Hand Side (ψ_4)
32°	25°	8.9°	8.5°
33°	24°	11.5°	11.0°
34°	23°	14.0°	13.5°
35°	22°	16.5°	16.0°
36°	21°	19.1°	18.6°
37°	20°	21.7°	21.1°
38°	19°	24.3°	23.7°
39°	18°	26.9°	26.3°
40°	17°	29.6°	29.0°
41°	16°	32.3°	31.7°
42°	15°	35.1°	34.4°

Meanwhile, where the prisms are made of a polycarbonate resin material, the refraction index is n=1.59, and calculations depending upon similar conditions to the acrylic resin material lead to the following results. Here, Ψ=55 degrees (only examples of calculations are given wherein the difference in emergent angle between two light rays from the left and right sides falls within 2 degrees).

θ_1	θ_2	Light from the Left-Hand Side (ϕ_5)	Light from the Right-Hand Side (ψ_5)
32°	25°	9.7°	8.4°
33°	24°	12.4°	11.0°
34°	23°	15.0°	13.6°
35°	22°	17.7°	16.2°
36°	21°	20.3°	18.9°
37°	20°	23.1°	21.6°
38°	19°	25.8°	24.3°
39°	18°	28.6°	27.0°
40°	17°	31.4°	29.8°
41°	16°	34.3°	32.6°

While in the case of the embodiments of FIGS. 10 and 11 the lens units 16 are formed on the first light emitting surface of the light guide of the first element 50, similar effects can be attained otherwise by forming lens units on a surface opposite to the first light emitting surface of the light guide of the first element or else by forming lens units on both of the light emitting surface and the opposite surface of the light guide if characteristics of the lens units are suitably selected.

FIG. 12 is a partial sectional view of a plane light source unit together with a lamp showing a further embodiment of the present invention.

Referring to FIG. 12, reference numeral 14 represents a light source such as a fluorescent lamp, 15 a reflector, 13 a reflecting layer formed on the opposite side to a first light emitting surface 12 of a first element 50, and 60 a mat finished first light emitting surface, which is substantially parallel to the reflecting layer 13. Reference numeral 40 represents a prism unit of a second element, and 32 a second light emitting surface of the prism units 40. The prism units 40 have a convex linear configuration extending in a direction parallel to the light source (lamp).

The plane light source unit of the present embodiment thus comprises a first element 50 having a light incident face at least at one side end 11 thereof and a mat finished first light emitting surface 12 which extends a perpendicular direction to the incident face, the first element 50 further having a reflecting layer 13 on the opposite surface thereof to the first light emitting surface, and a second element 51 having an incident surface on which the prism units 40 into which light from the first element 50 is introduced and from which light rays emerge in predetermined directions are formed and a second light emitting surface 32.

Light rays emerging from the first element are caused to emerge from the second element as represented by light rays 54 and 55, and the object of the invention can be attained by setting the prism units such that the angles Ψ_6 and ϕ_6 may be substantially equal to each other.

Subsequently, determination of prism angles where the primary emergent rays from the first element emerge symmetrically to each other with respect to the normal line is carried out in a similar manner to those of FIGS. 10 and 11.

Thus, where the prisms are made of an acrylic resin material, the refraction index is n=1.49, and if it is assumed that the incident angles to the prisms 40 are symmetrical and Ψ=65 degrees with respect to the normal line, the emergent angles of emergent rays of light from the prisms calculated in accordance with the expressions given hereinabove are concentrated on the one side with respect to the normal line (only examples of calculations are given wherein the difference in emergent angle between two light rays from the left and right sides falls within 2 degrees).

θ_1	θ_2	Light from the Left-Hand Side (ϕ_6)	Light from the Right-Hand Side (ψ_6)
35°	28°	8.5°	8.9°
36°	27°	11.0°	11.5°
37°	26°	13.5°	14.0°
38°	25°	16.0°	16.5°
39°	24°	18.6°	19.1°
40°	23°	21.1°	21.7°
41°	22°	23.7°	24.3°
42°	21°	26.3°	26.9°
43°	20°	29.0°	29.6°

FIGS. 13 and 14 are partial sectional views of plane light source unit together with a lamp, showing still further embodiments of the present invention.

Referring to FIG. 13, a first element (light guide) 50-1 has such a configuration that the opposite side to a first light emitting surface 12 is formed as mat finished surface 60 and is disposed opposing to a reflecting layer 13, and the first light emitting surface 12 of the first element 50-1 is formed as a smooth surface. FIG. 14 shows an example of construction wherein a first element 50-2 is

ated in which upper and lower surfaces are formed as mat finished surfaces 60. It is to be noted that the description that an imaginary plane of mat finished first light emitting surface of a light guide extends substantially in a parallel relationship to the reflecting layer 13 in the present invention means that the first element is a member in the form of a plate having a uniform thickness, and therefore the present invention has an advantage that it employs a transparent member which can be readily produced and assembled.

In the following, there are described various examples of construction of the present invention which are designed for backlighting for a 3-inch liquid crystal TV set and wherein the size of a panel is 61 mm long × 56 mm wide.

While the examples of construction of the present invention described below were produced using a plate of a transparent acrylic resin material having a thickness of 5 mm for the first element and another plate of an acrylic resin material or a polycarbonate resin material having a thickness of 1 mm for the second element, it is apparent that the sizes and the materials are not limited to such specific ones.

EXAMPLES

Example 1-1

Using a metal mold for convex cylindrical lenticular lenses of smooth curved surfaces wherein the pitch is 0.38 mm and the height of the curved lens surfaces is 0.051 mm (refer to FIG. 15), the lens pattern of the metal mold was transferred to an acrylic resin plate having a thickness of 5 mm by thermal press work to make a first element. Meanwhile, a viewing angle and an inclination angle from the normal line to the picture plane of a portable liquid crystal TV set were measured and the emergent angle was determined so that it might be 15 degrees ($\Psi_6 = \phi_6$) with respect to the normal line to the picture plane while the prism angles were set to 35 degrees ($=\theta_1$) on the left-hand side and 22 degrees on the right-hand side ($=\theta_2$) (refer to FIGS. 6(a) and 6(b)). Then, a metal mold having a multi-prism pattern wherein the pitch was 0.38 mm and each of the thus set prisms had an apex angle ($=\theta_1+\theta_2$) of 57 degrees was produced, and using the metal mold, the multi-prism pattern was transferred to an acrylic resin plate having a thickness of 1 mm by thermal press work to make a second element. The first and second elements were cut in predetermined sizes.

Subsequently, the two opposite sides of the first element having the length of 61 mm were polished by a conventional polishing method while aluminum vacuum deposited polyester films with an adhesive layer were applied to the other opposite sides having the width of 56 mm, and another silver vacuum deposited polyester film was secured on the surface opposing to the transferred lens surface. A fluorescent lamp having a diameter of 8 mm and a length of 90 mm (FLE-8.90 ADIPS 3 by Elevam Corp.) was arranged on each of the two sides of 61 mm length of the first element, and a reflector made of aluminum foil was applied to each of the lamps. Each lamp was then lit by means of DC 5 V power supply with an invertor. Luminance was then measured at the points near the lamps and the central point on a center line of the first element (refer to FIG. 5(a)) at various angles with respect to the normal line by means of a luminance meter (luminance meter nt-1 by Minolta Camera Co., Ltd.), and angular distributions of light were determined (refer to FIG. 5(b)). The data obtained in this manner are illustrated in FIGS. 4(a) and 4(b) mentioned hereinabove. Maximum luminance values of those points are listed in Table 1 below.

TABLE 1

Luminance Values observed at 55 degrees on the left and right side, respectively; at the central point	3,500 cd/m², 3,200 cd/m²
Luminance values observed at 55 degrees on the left and right side, respectively; at point spaced by 10 mm from the lamp	4,000 cd/m², 3,800 cd/m²

Further, the second element was arranged on the first element with the prism side of the former opposed to the lens side of the latter and was secured to the sides of the image by means of double-sided adhesive tapes having a width of about 5 mm. Then, similar measurements to those of the first element were carried out by a quite same method, and angular distributions of light were determined. The data thus obtained are illustrated in FIGS. 16(a), 16(b) and 16(c). Maximum luminance values and angles at which the maximum luminance value was observed are listed in Table 2 below.

TABLE 2

	Maximum Luminance Value	Angle
Central Point 1	3,300 cd/m²	15°
10 mm Point from Lamp 2	3,500 cd/m²	20°
10 mm Point from Lamp 3	3,700 cd/m²	12°

The angles at which the maximum luminance value was observed fall within a narrow range from 12 to 20 degrees, and the half-width of angular distribution is about 40 degrees.

It is to be noted that the luminance value of lamp surface in the present example was 10,000 cd/m².

Example 1-2

The same first element as in the example 1-1 described above was used, and while the same metal mold for preparing the second element as in the example 1-1 was used, the second element was produced from a polycarbonate resin plate having a thickness of 1 mm. Then, angular distributions of light were measured in luminance value by the similar setting to that of the example 1-1. The resultant data are illustrated in FIGS. 17(a) and 17(b). Meanwhile, maximum luminance values and angles at which the maximum luminance value was observed are listed in Table 3 below.

TABLE 3

	Maximum Luminance Value	Angle
Central Point 1	3,200 cd/m²	17°
10 mm Point from Lamp 2	3,700 cd/m²	23°
10 mm Point from Lamp 3	3,400 cd/m²	12°

Example 1-3

The same first element as in the example 1-1 was used. While it is a requirement that the emergent angle of emergent light rays from a first element be 60 degrees in

order to emit light from a plane light source unit in the direction of the normal line, because more than 90 percent of the maximum luminance value is exhibited at the angle of 60 degrees as can be seen from FIGS. 4(*a*) and 4(*b*), a metal mold for a multi-prism pattern wherein the prism angles were set to $\theta_1=\theta_2=30$ degrees and the prism pitch was set to 0.38 mm was produced, and the multi-prism pattern was thermally transferred to an acrylic resin plate of a thickness of 1 mm to make a second element.

Angular distributions of light were measured in luminance value with quite similar settings to those of the example 1-1 described hereinabove. The resultant data are illustrated in FIGS. 18(*a*), 18(*b*) and 18(*c*). Meanwhile, maximum luminance values and angles at which the maximum luminance value was observed are listed in Table 4 below.

TABLE 4

	Maximum Luminance Value	Angle
Central Point 1	2,900 cd/m²	0°
10 mm Point from Lamp 2	3,100 cd/m²	−5°
10 mm Point from Lamp 3	3,200 cd/m²	7°

Comparative Example

Acrylic resin pellet (HIPET HBS [trade mark] by Mitsubishi Rayon Co., Ltd.) was dry-blended with 1.5 percent by weight of rutile type titanium oxide and molded into a film of 50 microns thickness by a conventional extruder. The film was extended on an inorganic flat glass plate so as not to include air bubbles, and after being provisionally secured with methylmethacrylate, a cell was formed with glass plates by means of a spacer in a conventional manner. Methylmethacrylate syrup was poured in the clearance of the cell and polymerized to cure by a conventional manner to obtain an acrylic resin plate of 5 mm thickness.

The plate produced in this manner was cut into a size of 61 mm length×56 mm width, and the two sides of 61 mm length were polished in a conventional manner while aluminum vacuum deposited films with an adhesive layer were adhered to the other opposite sides of 56 mm width, whereafter a silver vacuum deposited polyester film (similar to that of the example 1-1) was arranged on the surface opposite to a white thin layer formed on the surface of the plate. Subsequently, evaluation was made by a quite same method as the measuring method of the first element of the example 1-1. The resultant data are illustrated in FIGS. 19(*a*) and 19(*b*). Meanwhile, luminance values at the specific points are listed in Table 5 below.

TABLE 5

	Maximum Luminance Value
Central Point 1	900 cd/m²
10 mm Points from Lamp 2 & 3	1,200 cd/m²

Summary

As can be seen from comparison between, for example, FIGS. 16(*a*), 16(*b*) and 16(*c*) and FIGS. 19(*a*) and 19(*b*), while the plane light source unit produced in comparative example has a characteristic that light is emitted uniformly in all directions, the plane light source unit produced in accordance with the present invention has advantages that light is emitted in particular direction and that the maximum luminance value at the central point is higher, about 3.5 times, than that obtained in comparative example.

Example 2

Production of Various First Elements

As described hereinabove, the lenses 16 of the first element may have any configuration only if light is concentrated in particular directions so that the angular distribution of light falls within narrow ranges and the amount of emitted light is large, and the configuration of the lenses 16 is not particularly limited. As examples of such lens configurations, first elements having lenses of the following configurations were produced including the first element of the convex cylindrical lenticular lenses in the examples 1-1 to 1-3 described hereinabove.

(1) Lens which has a substantially similar configuration to that of the convex cylindrical lenticular lens shown in FIG. 15 and wherein

Pitch P=0.38 mm,
Height H=0.05 mm, and
Thickness of the first element t=6 mm.

(2) Triangular pole-shaped lenticular lens which has such a configuration as shown in FIG. 20 and wherein

Pitch P=0.5 mm,
Apex Angle $\theta=25$ degrees, and
Thickness of the first element t=6 mm.

(3) Concave cylindrical lenticular lens which has such a configuration as shown in FIG. 21 and wherein

Pitch P=0.5 mm,
Depth D=0.06 mm, and
Thickness of the first element t=6 mm.

(4) Polygonal pole-shaped lenticular lens which has such a configuration as shown in FIG. 22 and wherein

Pitch P_1=0.10 mm, $\theta_1=30$ degrees,
Pitch P_2=0.15 mm, $\theta_2=10$ degrees,
Pitch P_3=0.15 mm, $\theta_3=5$ degrees,
Pitch P=0.8 mm,
Height H=0.097 mm, and
Thickness of the first element t=6 mm.

(5) Anisotropic lenticular lenses

① Anisotropic lenticular lens A which has such a configuration as shown in FIG. 23(*a*) and wherein
Pitch P=0.41 mm,
Height H_1=0.051 mm, and
Thickness of the first element t=6 mm.

② Anisotropic lenticular lens B which has such a configuration as shown in FIG. 23(*b*) and wherein
Pitch P=0.41 mm,
Height H_2=0.102 mm, and
Thickness of the first element t=6 mm.

The first elements were produced by transferring lens patterns to acrylic resin plates of 6 mm thickness by thermal press work using metal molds which have individually such predetermined configurations as described above.

Light Emitting Characteristics of Individual First Elements

Angular distributions of light of the individual first elements were determined by a similar method to that described hereinabove with reference to FIG. 5(*b*). In particular, the two sides of 61 mm length of each of the first elements were polished by a conventional method while aluminum vacuum deposited polyester films with

an adhesive layer were applied to the other two sides of 56 mm width. Then, a silver vacuum deposited polyester film was secured on a surface of each first element opposing to the thus transferred lens surface, and then a fluorescent lamp having a diameter of 8 mm and a length of 90 mm (FLE-8.90 ADIP 3 by Elevam Corp.) was arranged on each of the two sides of 61 mm length of each first element with aluminum foil applied as a reflector, whereafter the lamp was lit by means of DC 5 V power supply with an invertor. The construction in this case will be hereinafter referred to as front type. It is to be noted that, before angular distributions of light were examined, in order to make sure that such a construction can be adopted that a reflecting layer is positioned on the surface of lenses 16 such that light emitted from the lenses 16 may be reflected by the reflecting layer and then, after being transmitted through the first element 80, is emitted through the emitting surface on the opposite side to the lenses 16 (hereinafter referred to as reverse type), the lens surfaces of the first elements (1) to (5) specified as above were faced a mirror and angular distributions of such emitted light were measured. The manner of such measurement is illustrated in FIG. 24 by way of example of the concave cylindrical lenticular lens. In FIG. 24, reference numeral 13 represents a mirror.

RESULTS OF MEASUREMENTS OF ANGULAR DISTRIBUTIONS OF LIGHT

(1) FIG. 25(b) illustrates the angular distribution of light from the first element of the reverse type in which the convex cylindrical lenticular lenses of the configuration shown in FIG. 15 were employed. Meanwhile, the angular distribution of light from the first element of the front type is illustrated in FIG. 25(a). The maximum luminance value appeared in the direction of about 70 degrees from the normal line in the case of the first element of the reverse type but in the direction of about 70 to 80 degrees from the normal line in the case of the first element of the front type.

(2) FIG. 26(a) illustrates the angular distribution of light from the first element of the front type in which the triangular pole-shaped lenticular lenses were employed. Meanwhile, the angular distribution of light from the first element of the reverse surface type is illustrated in FIG. 26(b). The maximum luminance value appeared in the direction of 70 to 80 degrees from the normal line in the case of the first element of the front type but in the direction of 30 to 35 degrees from the normal line in the case of the first element of the reverse type.

(3) FIG. 27(a) illustrates the angular distribution of light from the first element of the front type in which the concave cylindrical lenticular lenses were employed. Meanwhile, the angular distribution of light from the first element of the reverse type is illustrated in FIG. 27(b). The maximum luminance value appeared in the direction of 75 to 80 degrees from the normal line in the case of the first elements of both of the front and reverse types.

(4) FIG. 28(a) illustrates the angular distribution of light from the first element of the front type in which the convex polygonal pole-shaped lenticular lenses were employed. Meanwhile, the angular distribution of light from the first element of the reverse type is illustrated in FIG. 28(b). The maximum luminance value appeared in the direction of 75 to 80 degrees from the normal line in the case of the first elements of both of the front and reverse types.

(5) The angular distribution of light from the first element in which the anisotropic lenticular lenses A were employed is illustrated in FIG. 29(a). Meanwhile, the angular distribution of light from the first element in which the anisotropic lenticular lenses B were employed is illustrated in FIG. 29(b). The maximum luminance value appeared in the direction of about 60 degrees from the normal line in the case of the first element in which the anisotropic lenticular lenses A were employed and in the direction of about 50 degrees from the normal line in the case of the first element in which the anisotropic lenticular lenses B were employed.

Production of Plane Light Source Units

The second element described hereinabove (substantially same as that used in the examples 1-1 to 1-3) was placed on a surface of each of the first elements produced in such a manner as described above in accordance with the configuration of the latter to produce plane light source units in each of which the lens surface 16 was located on the side of the emitting surface 12 of the first element (i.e., the front type).

On the other hand, a silver vacuum deposited polyester film was secured on the lens surface of each of the first elements, and the second element described hereinabove (substantially same as that used in the examples 1-1 to 1-3) was placed on the surface opposing to the lens surface of each of the first elements to produce plane light source units of a construction in which the lens surface 16 is located on the opposite side to the emitting surface 12 of the first element (i.e., the reverse type). As examples of such plane light source units, plane light source units of the front and reverse types wherein the concave lenticular lenses were employed are shown in FIGS. 30(a) and 30(b), respectively.

Measurements of Luminance and So on of Individual Plane Light Source Units

Maximum luminance values and angles at which the maximum luminance value was observed as well as half-width of angular distribution were examined for such individual plane light source units described above. The results are listed in Table 6 below. Here, the half-width shows an angular range within which the luminance value is equal to or greater than 50 percent of the maximum luminance value.

TABLE 6

Luminances of Plane Light Source Units in Which Various Light Guides Are Employed

Lenticular Shape of First Element	Type	Apex Angle of Second Element Prism	Maximum Luminance Value	Angle	Half-Width
Convex-Cylindrical (FIG. 15)	Front	63°	3,200 Cd/m^2	16°	57°
	Reverse	63°	3,000 Cd/m^2	17°	77°
Triangular Pole (FIG. 20)	Front	66°	2,350 Cd/m^2	15°	75°
	Reverse	30°	2,300 Cd/m^2	16°	90°
Concave Cylindrical (FIG. 21)	Front	63°	3,100 Cd/m^2	14°	60°
	Reverse	63°	2,950 Cd/m^2	14°	60°
Convex Polygonal Pole (FIG. 22)	Front	63°	3,140 Cd/m^2	16°	85°
	Reverse	63°	3,080 Cd/m^2	14°	65°
Aniso-	A	52°	3,450 Cd/m^2	16°	95°

TABLE 6-continued

Luminances of Plane Light Source Units in Which Various Light Guides Are Employed

Lenticular Shape of First Element	Type	Apex Angle of Second Element Prism	Maximum Luminance Value	Angle	Half-Width
tropic (FIG. 23)	B	52°	3,800 Cd/m^2	16°	55°

As can be seen from Table 6 above, as for the plane light source units which include the first elements of the convex cylindrical lenticular, triangular pole-shaped lenticular, concave cylindrical lenticular and convex polygonal pole-shaped lenticular lens units, the luminance is a little lower in the case of the reverse type than in the case of the front type, but the difference is very little. Accordingly, they can be satisfactory for practical use whether the first elements are either of the front type or of the reverse type.

Angular Distributions of Light from the Individual Plane Light Source Units

Angular distributions of light from the individual plane light source units at the central point (point of 1 of FIG. 8(a)) were measured in accordance with the measurements of angular distributions of light from the first elements described hereinabove.

(1) FIG. 31(b) shows the angular distribution of light from the plane light source unit of the reverse type in which the first element having the convex cylindrical lenticular lenses of the configuration shown in FIG. 15 was employed. Meanwhile, the angular distribution of light from the plane light source unit of the front type is shown in FIG. 31(a). In the case of the plane light source unit of the front type, the maximum luminance value appeared in the direction of 15 to 20 degrees and the half-width was about 57 degrees. To the contrary, in the case of the plane light source unit of the reverse type, the maximum luminance value appeared in the direction of 15 to 20 degrees and the half-width was about 77 degrees.

(2) FIG. 32(a) shows the angular distribution of light from the plane light source unit of the front type in which the first element having the triangular pole-shaped lenticular lenses was employed. Meanwhile, the angular distribution of light from the plane light source unit of the reverse type is shown in FIG. 32(b). In the case of the plane light source unit of the front type, the maximum luminance value appeared in the direction of 13 to 15 degrees and the half-width was about 75 degrees. To the contrary, in the case of the plane light source unit of the reverse type, the maximum luminance value appeared in the direction of 15 to 17 degrees and the half-width was about 90 degrees.

(3) FIG. 33(a) shows the angular distribution of light from the plane light source unit of the front type in which the first element having the concave cylindrical lenticular lenses was employed. Meanwhile, the angular distribution of light from the plane light source unit of the reverse type is shown in FIG. 33(b). In the case of the plane light source unit of the front type, the maximum luminance value appeared in the direction of 13 to 15 degrees and the half-width was about 60 degrees. To the contrary, in the case of the plane light source unit of the reverse type, the maximum luminance value appeared in the direction of 13 to 15 degrees and the half-width was about 60 degrees.

(4) FIG. 34(a) shows the angular distribution of light from the plane light source unit of the front type in which the first element having the convex polygonal pole-shaped lenticular lenses was employed. Meanwhile, the angular distribution of light from the plane light source unit of the reverse type is shown in FIG. 34(b). In the case of the plane light source unit of the front type, the maximum luminance value appeared in the direction of 15 to 17 degrees and the half-width was about 85 degrees. To the contrary, in the case of the plane light source unit of the reverse type, the maximum luminance value appeared in the direction of 13 to 15 degrees and the half-width was about 65 degrees.

(5) FIG. 35(a) shows the angular distribution of light from the plane light source unit in which the first element having the anisotropic lenticular lenses A was employed. Meanwhile, FIG. 35(b) shows the angular distribution of light from the plane light source unit in which the first element having the anisotropic lenticular lenses B was employed. In the case of the plane light source unit employing the first element having the anisotropic lenticular lenses A, the maximum luminance value appeared in the direction of 15 to 17 degrees and the half-width was about 95 degrees. To the contrary, in the case of the plane light source unit employing the first element having the anisotropic lenticular lenses B, the maximum luminance value appeared in the direction of 13 to 17 degrees and the half-width was about 55 degrees.

Summary

Whether the first element emits the light symmetrically or asymmetrically with respect to the normal line as seen in FIGS. 28(a) to 29(b), the light is emitted by the second element in particular direction as seen in FIGS. 31(a) to 35(b) and Table 6 above and the maximum luminance value is sufficient for practical use, about 2 to 3.5 times that of the cases of non-directional light emission, provided that the second element has an appropriate configuration.

Example 3

Production and Evaluation of Example of Construction Shown in FIG. 13

Production of First Element

At first, a surface of a metal plate was treated by a conventional honing technique wherein glass beads of 60 mesh were blown to one face of a polished brass plate (about 3 mm×250 mm×250 mm) to produce a metal mold having a mat finished surface. Actually, five different kinds of metal molds were produced by varying the treating condition.

Subsequently, using the metal molds, the mat pattern was transferred to one surface of each of acrylic resin plates having a thickness of 5 mm by thermal press work to make a first element.

Production of Second Element

A viewing angle and an inclination angle from the normal line to the picture plane of a portable liquid crystal TV set (refer to FIG. 1) were measured, and the emergent angle was determined so that it might be 15 degrees ($\Psi_6=\phi_6$) with respect to the normal line to the picture plane while the prism angles were set to 38 degrees ($=\theta_1$) on the left-hand side and 25 degrees on

the right-hand side ($=\theta_2$) (refer to FIGS. 6(*a*) and 6(*b*)). Then, a metal mold having a multi-prism pattern wherein the pitch was 0.38 mm and each of the thus set prisms had an apex angle ($=\theta_1+\theta_2$) of 63 degrees was produced, and, using the metal mold, the multi-prism pattern was transferred to an acrylic resin plate having a thickness of 1 mm by thermal press work to make a second element.

Measurements of Haze Values of Light Guide for First Elements

(1) Specimens of a 50×50 mm size were cut off from the acrylic resin plate of 5 mm thickness having a mat finished surface produced in the preceding step (1) to obtain samples for measurement of haze values. As comparative samples, a transparent acrylic resin plate was cut similarly into pieces of a 50×50 mm size.

In order to measure haze values of the samples, they were put on a measuring instrument with the mat finished surfaces thereof directed toward the light incidence side in accordance with ASTM-D 1003-61, and the haze values were calculated in accordance with the following expression:

TABLE 7

Sample	Haze
Sample-1	70.8%
Sample-2	64.8
Sample-3	40.8
Sample-4	28.8
Sample-5	4.1
Comparative Sample	0.2

(2) Results of the measurements were such as listed in Table 7 below.

TABLE 7

Sample	Haze
Sample-1	70.8%
Sample-2	64.8
Sample-3	40.8
Sample-4	28.8
Sample-5	4.1
Comparative Sample	0.3

Production of and Evaluation of Angular Distributions of Light from First Elements

Subsequently, the acrylic resin plates were cut into pieces of 61 mm long×56 mm wide, and the two sides of 61 mm length of each of the pieces were polished by a conventional method while aluminum vacuum deposited polyester films with an adhesive layer were adhered to the other two sides of 56 mm width. Then, a silver vacuum deposited polyester film was secured on a surface opposing to the mat finished surface, and then a fluorescent lamp having a diameter of 7 mm and a length of 245 mm (CB7-245W cold cathode tube by Stanley Electric Co., Ltd.) was arranged on each of the two sides of 61 mm length with aluminum foil applied as a reflector, whereafter the lamp was lit by means of DC 12 V power supply with an invertor. Luminance was measured at the central point (point 1 shown in FIG. 9(*a*)) of the thus obtained first elements at various angles with respect to the normal line by means of a luminance meter (luminance meter nt-1 by Minolta Camera Co., Ltd.) to obtain angular distributions of light (refer to FIG. 9(*b*)).

The data obtained in this manner are listed in Table 8 below and illustrated in FIGS. 8(*a*) to 8(*d*). In FIGS. 8(*a*) to 8(*f*), a luminance value is represented in a radial direction and a light emergent angle is represented in a circumferential direction. Data of the sample-5 and the comparative sample are omitted from Table 8 below because the amount of emitted light is too small in any direction to attain accurate measurement.

TABLE 8

Sample No.	Maximum Luminance Values in Leftward & Rightward Directions	
	Left	Right
Sample-1	2,790	2,770 cd/m²
Sample-2	1,960	1,800
Sample-3	2,100	2,500
Sample-4	2,400	2,400

It is to be noted that the luminance values of lamp surface at the central portion were 5,000 and 5,200 cd/cm².

Production and Evaluation of Plane Light Source Units According to the Present Invention

The aforementioned second element was cut into pieces of 61 mm length and 56 mm width such that the multi-prisms thereof might extend in parallel to the longitudinal edges of the pieces, and the second element pieces were arranged on the first elements such that the prism surfaces thereof might face the first light emitting surfaces of the first elements whereafter they were secured along the sides of the lamps (the sides of 61 mm length) with double-sided adhesive tapes of about 5 mm width to produce plane light source units according to the present invention.

Angular distributions of light from the plane light source units were measured by a quite similar method as the method of evaluation of angular distributions of light from the first elements described hereinabove. Results of the measurements are listed in Table 9 below and illustrated in FIGS. 36(*a*) to 36(*d*).

TABLE 9

Sample No.	Maximum Luminance Value	Angle	Half-Width	Haze of 1st Element
Sample-1	1,660 cd/m²	15°	45° (−12°, 33°)	70.8%
Sample-2	1,450	15°	48° (−15°, 33°)	64.8
Sample-3	1,300	15°	49° (−12°, 37°)	40.8
Sample-4	1,340	15°	42° (−10°, 32°)	28.8

From the results, it can be seen that a sufficient luminance and a sufficient half-width for a plane light source unit can be obtained where the haze value is higher than about 30 percent, preferably higher than 50 percent.

Example 4

Production and Evaluation of Examples of Constructions Shown in FIGS. 13 and 14

Using the metal mold with which the sample-2 of the example 3 described above was produced, the mat pattern was transferred to both surfaces of an acrylic resin plate of 5 mm thickness to make a sample-6. This sample corresponds to the first element 50-2 shown in FIG. 14.

Measurement of Haze Value of Light Guide

A haze value of the sample-6 was measured by a quite same method as in the example 3 described above.

	Haze
Sample-6	81.5%

Production of and Evaluation of Angular Distribution of Light from First Element

Using the sample-2 and the sample-6 as light guide, first elements were produced in a quite same manner as in the example 3 described hereinabove, where the sample-2 was used after the silver vacuum deposited polyester film was arranged on the mat finished surface of the same light guide (refer to FIG. 13). The sample of such arrangement will be hereinafter referred to as sample-7. The sample-7 corresponds to the light guide 50-1 shown in FIG. 13. Results of measurements of angular distributions of light are listed in Table 10 below and illustrated in FIGS. 8(e) and 8(f).

TABLE 10

Sample No.	Maximum Luminance Values in Leftward & Rightward Directions	
	Left	Right
Sample-6	1,600 cd/m^2	1,700 cd/m^2
Sample-7	1,800	1,750

Luminance values of lamp surface at the central portion were 5,000 and 5,200 cd/m^2.

Production and Evaluation of Plane Light Source Units According to the Present Invention

Plane light source units were produced, and angular distributions of light from the plane light source units were measured in a quite similar manner as in the example 3 described above.

Resultant data are listed in Table 11 below and illustrated in FIGS. 36(e) and 36(f).

TABLE 11

Sample No.	Maximum Luminance Value	Angle	Half-Width	Haze of Light Guide
Sample-6	1,250 cd/m^2	15°	61° (−23°, 38°)	81.5%
Sample-7	1,270	15°	52° (−12°, 40°)	64.8

From the results, it can be seen that the angular distribution of light can become broad where both surfaces of a light guide were mat finished (sample-6) or a surface in contact with a reflecting layer was mat finished (sample-7) (the maximum luminance value is decreased as much).

Comparative Example

Acrylic resin pellet (HIPET HBS [trade mark] by Mitsubishi Rayon Co., Ltd.) was dry-blended with 1.5 percent by weight of rutile type titanium oxide and molded into a film of 50 microns thickness by a conventional extruder. The film was extended on an inorganic flat glass plate so as not to include air bubbles, and after being provisionally secured with methylmethacrylate, a cell was formed with glass plates by means of a spacer in a conventional manner. Methylmethacrylate syrup was poured in the clearance of the cell and polymerized to cure by a conventional manner to polymerize and solidify the film to obtain an acrylic resin plate of 5 mm thickness.

The plate produced in this manner was cut into a size of 61 mm length × 56 mm width, and the two sides of 61 mm length were polished in a conventional manner while aluminum vacuum deposited films with an adhesive layer were applied to the other opposite sides of 56 mm width, whereafter a silver vacuum deposited polyester film was arranged on the surface opposite to a white thin layer formed on the surface of the plate. Subsequently, measurements similar to those of the first elements described hereinabove were made by a quite same method to determine angular distributions of light. The resultant data are listed in Table 12 below and illustrated in FIG. 37.

TABLE 12

	Maximum Luminance Value	Angle/Half-Width
Evaluation	420 cd/m^2	0° (normal line direction)/ About 160° (−80°, 80°)

Summary

As can be seen from comparison between, for example, FIGS. 36(a) to 36(f) and FIG. 37, while the plane light source unit produced in comparative example has a characteristic that light is emitted uniformly in all directions, the plane light source unit of the present invention is advantageous in that light is emitted in particular direction and that the maximum luminance value at the central point is higher, about 3.5 to 4 times, than that obtained in comparative example.

Example 5

As an example wherein the light is emitted to the direction of the normal line to a picture plane, a second element was produced by thermal transfer to an acrylic resin plate of 1 mm thickness by thermal press work using a metal mold of a multi-prism pattern wherein the prism angles were set symmetrically to $\theta_1 = \theta_2 = 31.5$ degrees on the left and right sides and the pitch was set to 0.5 mm.

Using the element of the sample-1 of Table 8 above as a first element, a plane light source unit was produced and an angular distribution of light was measured in a quite similar manner as in the example 3 described hereinabove. Results of measurement of maximum luminance value of the first element are listed in Table 13 below while results of measurement of maximum luminance value of the plane light source unit are listed in Table 14 below, and an angular distribution of light from the plane light source unit is illustrated in FIG. 38.

TABLE 13

Sample No.	Maximum Luminance Values in Leftward and Rightward Directions (±80°)		Haze
	Left	Right	
Sample-1	2,790	2,770 cd/m^2	70.8%

TABLE 14

Maximum Luminance Value	Angle	Half-Width	Haze of Light Guide
1,780 cd/m²	0°	40° (−18°, 22°)	70.8 %

As can be seen from Table 14 above and FIG. 38, by setting the prism angles θ_1 and θ_2 in such a manner as described hereinabove, the plane light source unit was produced wherein light could be emitted in the normal line direction to the picture plane.

As apparent from the foregoing description, according to the present invention, the following effects are exhibited:

(1) A plane light source unit can be provided wherein light can be emitted readily at a desired direction without increasing the power consumption of a light source and which has a decreased thickness (substantially equal to a diameter of a lamp) and is advantageous for backlighting means for a display device which has a directivity of viewing angle such as a liquid crystal display device; and

(2) Directive light can be obtained readily using a fluorescent lamp which primarily is a source of diffused light, and a desired direction of emitted light can be determined readily similar to focusing of a convex lens.

Having now fully described the invention, it will be apparent to one of ordinary skill in the art that many changes and modifications can be made thereto without departing from the spirit and scope of the invention as set forth herein.

We claim:

1. A plane light source unit, comprising a first element having a light incident face at lest at one side end thereof and a first light emitting surface extending perpendicularly to said light incident face, said first element further having a reflecting layer provided on a surface thereof opposite to said first light emitting surface, and a second element having a light incident surface which receives the light emitted by said first element and a second light emitting surface through which light is emitted in a predetermined direction, at least one of said first light emitting surface and the opposite surface of said first element comprising means having a directive function to cause incident light through said light incident face to emit through said first light emitting surface in two preferential directions oblique to, and on opposite sides of, a normal line thereof; said second element having a large number of prism units formed on said light incident surface thereof, each prism unit having at least one surface positioned for effecting total reflection of the light received by said second element,

wherein the direction of substantially all of the light emitting from said second element makes an angle ranging from 0 degrees to 20 degrees with respect to a normal line of said first light emitting surface of said first element.

2. A plane light source unit according to claim 1, wherein either said first light emitting surface or the opposite surface of said first element has a large number of lens units formed thereon which contribute to the directive function.

3. A plane light source unit according to claim 2, wherein said large number of lens units are convex cylindrical lenticular lenses.

4. A plane light source unit according to claim 2, wherein said large number of lens units are concave cylindrical lenticular lenses.

5. A plane light source unit according to claim 2, wherein said large number of lens units are triangular pole-shaped lenticular lenses.

6. A plane light source unit according to claim 2, wherein said large number of lens units are polygonal pole-shaped lenticular lenses.

7. A plane light source unit according to claim 2, wherein said large number of lens units are anisotropic lenticular lenses.

8. A plane light source unit according to claim 1, wherein said first light emitting surface and/or the opposite surface of said first element has a mat finished surface which extends substantially in parallel to a plane of said reflecting layer and contribute to the directive function.

9. A plane light source unit according to claim 8, wherein a haze of said first element on which said mat finished surface is formed is equal to or greater than 30 percent.

10. A plane light source unit according to claim 1, wherein said first element has a pair of light incident surfaces at two opposing side ends thereof.

11. A plane light source unit according to claim 1, wherein said first element is made of an acrylic resin material.

12. A plane light source unit according to claim 1, wherein said first element is made of a polycarbonate resin material.

13. A plane light source unit according to claim 1, wherein said second element is made of an acrylic resin material.

14. A plane light source unit according to claim 1, wherein said second element is made of a polycarbonate resin material.

15. A plane light source unit according to claim 1, wherein the direction of light emitting from said first element makes an angle equal to or greater than 45 degrees and smaller than 90 degrees with respect to a normal line of said first light emitting surface of said first element.

* * * * *

Exhibit 17

REDACTED

Exhibit 18

REDACTED